Appendix D
Aquifer Test Data

FORMER C-6 FACILITY

Aquifer Testing and Analysis

DEL AMO STUDY AREA

Summaries of Aquifer Test Results

Map showing Aquifer Test Well Locations

FORMER C-6 FACILITY

Aquifer Testing and Analysis

RETURN TO C6 - ENVIRONM

Woodward-Clyde Consultants

DOUGLAS AIRCRAFT COMPANY
TORRANCE (C6) FACILITY
PHASE III GROUNDWATER AND SOIL
INVESTIGATION REPORT

Prepared for:

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Project No. 8941863J
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(2L-ABC/C6GW3-R)

TABLE 1
SLUG TEST DATA REDUCTION
DOUGLAS AIRCRAFT C6 FACILITY, TORRANCE CALIFORNIA

Where:

K = Hydraulic Conductivity
Rc = Radius of well casing in feet
Re = Effective Radius of influence (ft)
Yo = Initial drawdown at time t =0 (sec)
H = Distance from base of well to SWL (ft)
A = Constant Based on L/Rw
Yt = Drawdown at time t (sec)
Dw = Depth of well (ft)

Rw = Radius of Boring in feet
L = Length of screen of saturated thickness
  if entire screen is not saturated in feet
t = Selected time/drawdown semi-log plot (sec)
D = Thickness of aquifer in feet
  (Bottom of aquifer approx. 150 feet)
B = Constant based on L/Rw

Depth to water(ft) – Measured 19 July, 30 August, and 4 October 1989.

Parameter	WCC-4S		WCC-5S		WCC-7S		WCC-8S	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Rc	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Rw	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Dw	90	90	90	90	90	90	90	90
DTW	69.35	69.35	69.69	69.69	68.41	68.41	70.01	70.01
L = (Dw-DTW)*	20.65	20.65	20.31	20.31	21.59	21.59	19.99	19.99
D = (150-DTW)	80.65	80.65	80.31	80.31	81.59	81.59	79.99	79.99
H = (Dw-DTW)	20.65	20.65	20.31	20.31	21.59	21.59	19.99	19.99
A	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
B	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
L/Rw	49.17	49.17	48.36	48.36	51.40	51.40	47.60	47.60
Yo	0.87	1.5	0.65	2.05	0.84	1.5	0.94	1.5
Yt	0.28	0.33	0.16	0.61	0.38	0.7	0.62	1
t	20	20	11	10	20	20	20	20
Ln Re/Rw =	2.52584	2.52584	2.50616	2.50616	2.57881	2.57881	2.48737	2.48737
K (ft/sec) =	1.00E-04	1.34E-04	2.27E-04	2.16E-04	6.85E-05	6.58E-05	3.74E-05	3.65E-05
AVG K (ft/sec)	1.17E-04		2.22E-04		6.71E-05		3.69E-05	
AVG K (CM/SEC)	3.57E-03		6.76E-03		2.05E-03		1.13E-03	
AVG K (Gal/day/ft2)	7.56E+01		1.43E+02		4.34E+01		2.39E+01	

TABLE 1 (Continued)

Parameter	WCC-9S		WCC-10S		WCC-1D		WCC-3D	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Rc	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Rw	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Dw	90	90	90	90	140	140	140	140
DTW	67.17	67.17	69.51	69.51	70.09	70.09	70.62	70.62
L = (Dw-DTW)*	22.83	22.83	20.49	20.49	20	20	20	20
D = (150-DTW)	82.83	82.83	80.49	80.49	79.91	79.91	79.38	79.38
H = (Dw-DTW)	22.83	22.83	20.49	20.49	69.91	69.91	69.38	69.38
A	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
B	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
L/Rw	54.36	54.36	48.79	48.79	47.62	47.62	47.62	47.62
Yo	0.91	1.9	0.96	1.5	2.25	2.4	1.68	1.7
Yt	0.16	0.21	0.56	0.83	0.39	0.52	1.23	1.36
t	71	77	20	20	117	117	60	60
Ln Re/Rw =	2.64567	2.64567	2.51661	2.51661	3.19028	3.19028	3.18702	3.18702
K (ft/sec) =	4.10E-05	4.79E-05	4.78E-05	5.25E-05	3.45E-05	3.01E-05	1.20E-05	8.56E-06
AVG K (ft/sec)	4.44E-05		5.02E-05		3.23E-05		1.03E-05	
AVG K (CM/SEC)	1.36E-03		1.53E-03		9.86E-04		3.13E-04	
AVG K (Gal/day/ft2)	2.87E+01		3.24E+01		2.09E+01		6.63E+00	

TABLE 2

SUMMARY OF AQUIFER HYDRAULICS TESTING

Well No.	Hydraulic Conductivity (gpd/ft²) Slug Test[a]	Pump Test	Pump Test[b] Analysis Method	Coefficient of Storativity (S) (from pump test)
1S	--	460	Cooper Jacob	0.014
2S	NT	NM	--	--
3S	NT	ND	--	--
4S	76	470	residual drawdown	--
5S	140	NM	--	--
6S	NT	970	Cooper Jacob	0.004
7S	43	970	Cooper Jacob	0.013
8S	24	560	Cooper Jacob	0.009
9S	29	NR	--	--
10S	32	NM	--	--
1D	NT	NR	--	--
3D	6.6	NM	--	--
1S, 6S, 7S, 8S	--	860	Distance drawdown (500 minutes)	0.007

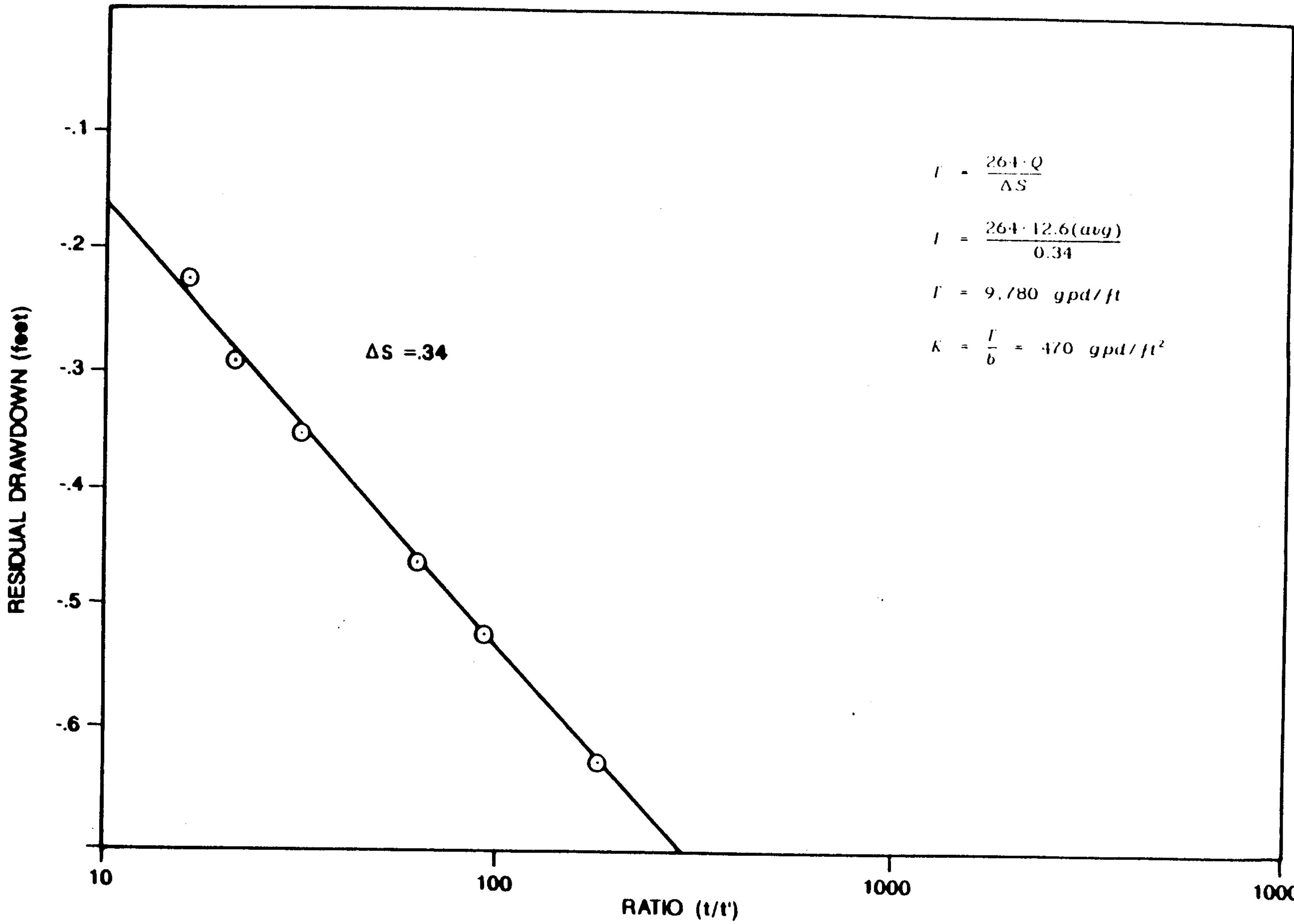
a Slug test values included for reference, generally not directly comparable to pump test values.

b WCC-4S was pumping well.

NT Not tested.

NR Not responsive.

NM Not monitored.



PUMPING WELL (WCC-4S) - RESIDUAL DRAWDOWN PLOT

Project No.: 8941863J	Date: FEB. 1990	Project: DOUGLAS AIRCRAFT CO.	Fig A-23

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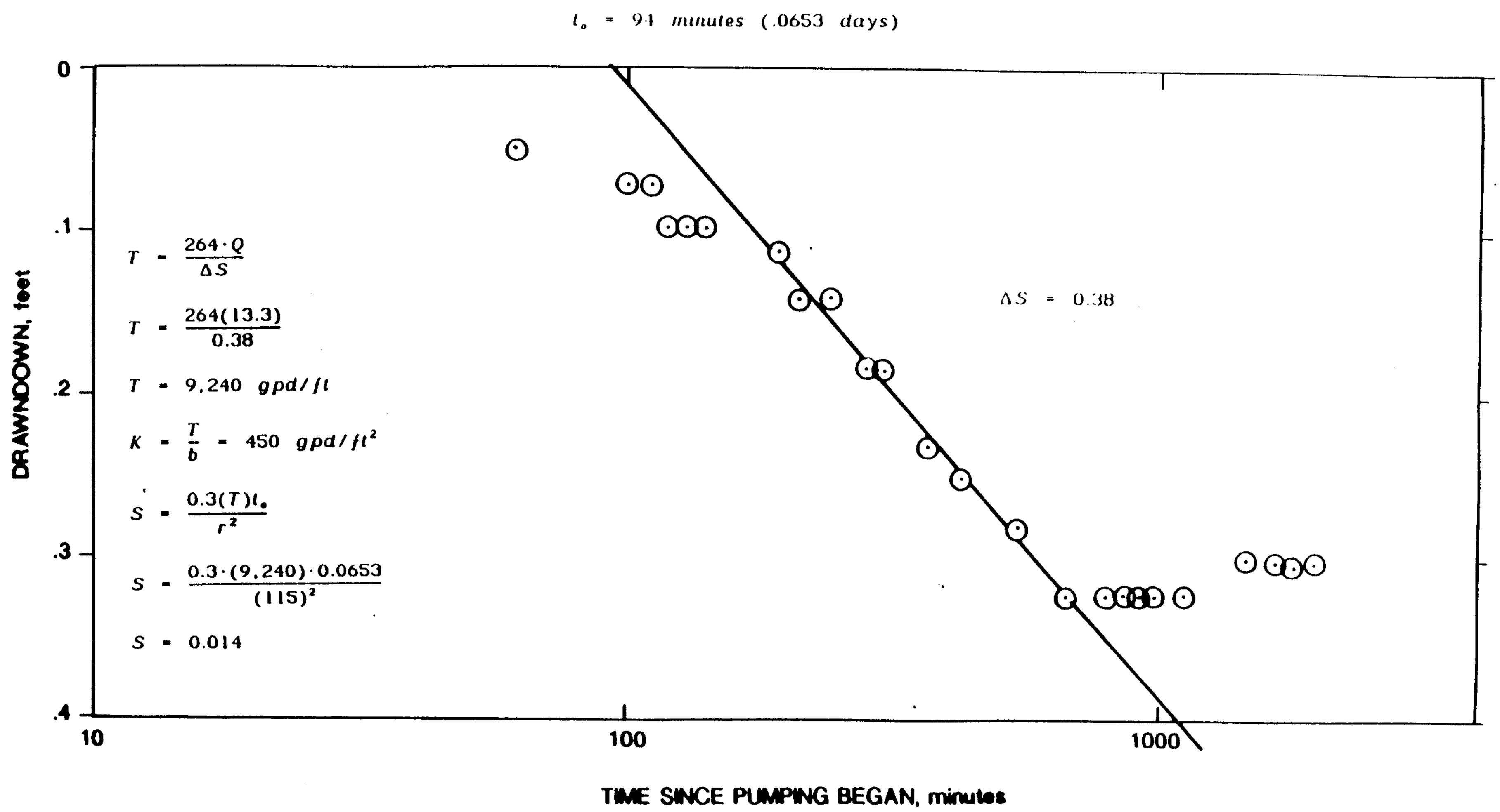

WCC-1S: COOPER-JACOB PLOT

Project No.: 8941863J	Date: MARCH 1990	Project: DOUGLAS AIRCRAFT CO.	Fig. A-24

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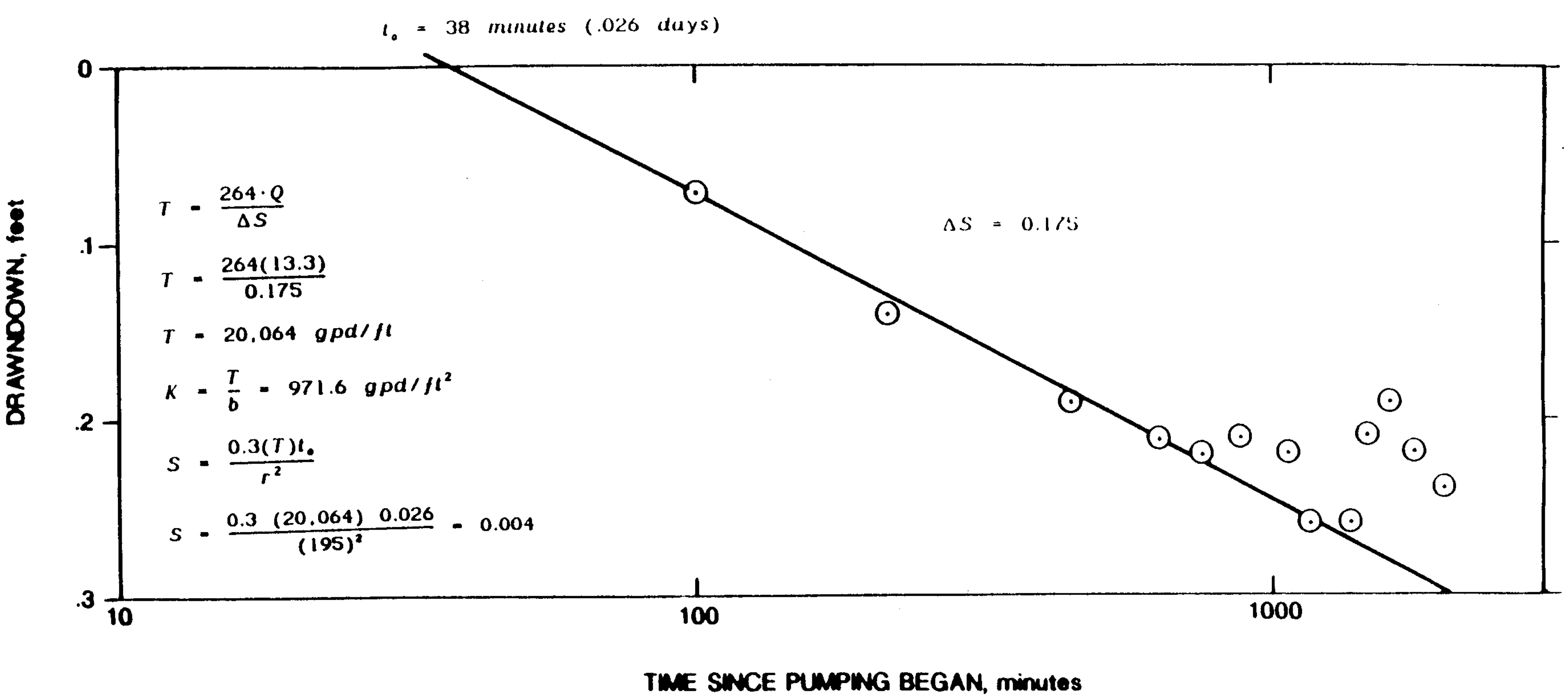

WCC-6S: COOPER-JACOB PLOT

Project No.: 8941863J	Date: MARCH 1990	Project: DOUGLAS AIRCRAFT CO.	Fig A-25

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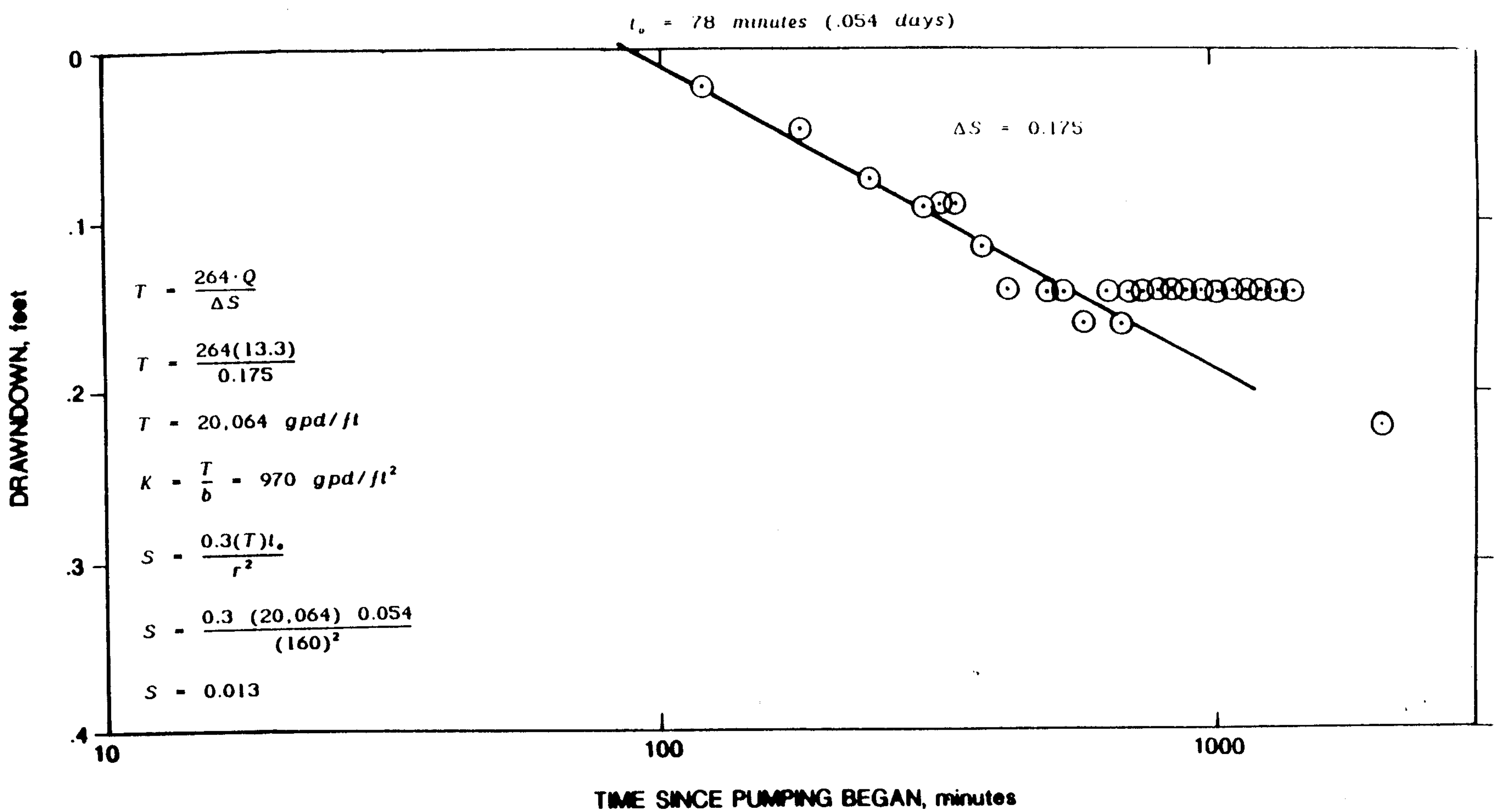
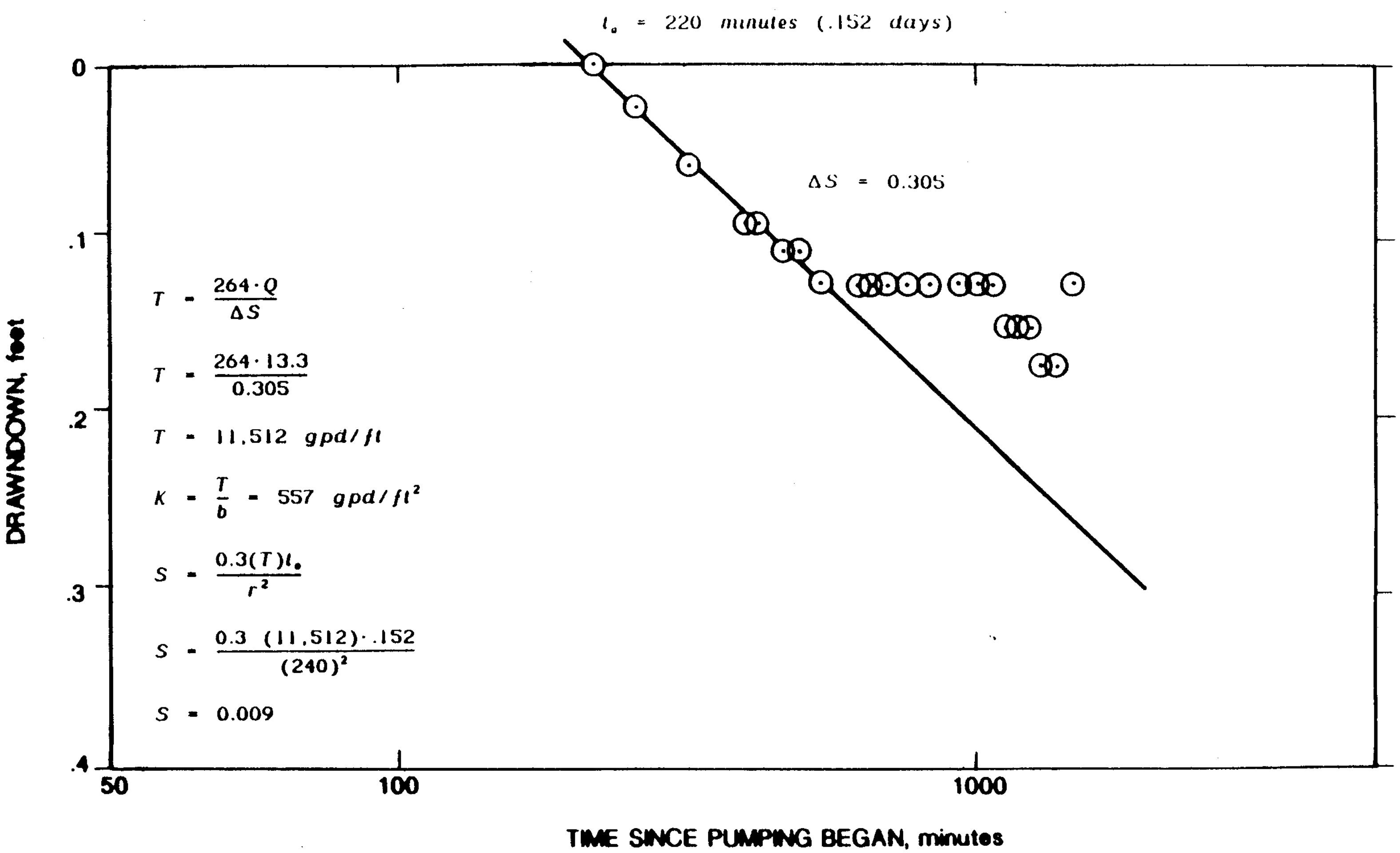
BOE-C6-0210577



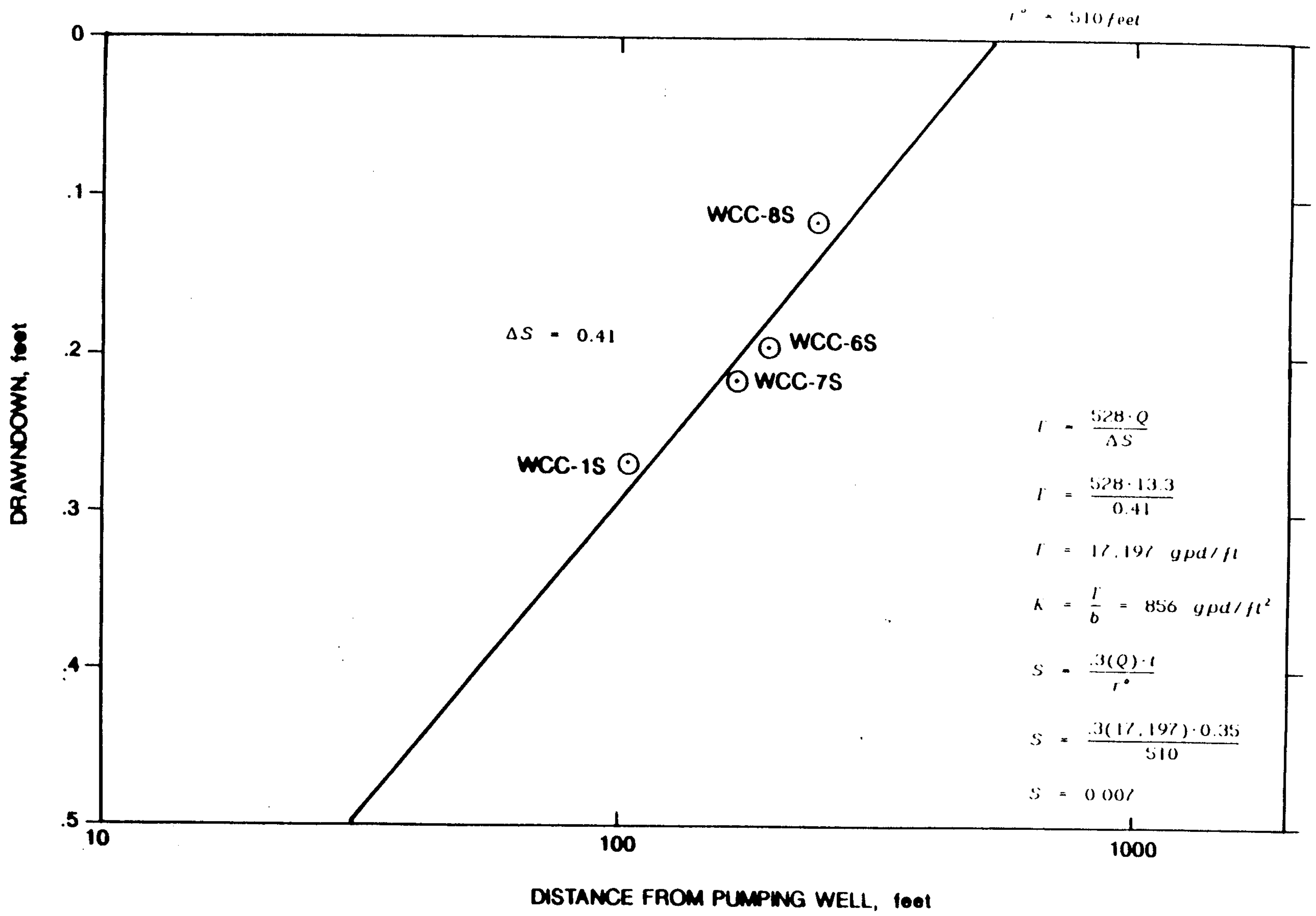
WCC-7S: COOPER-JACOB PLOT			
Project No.: 8941863J	Date: MARCH 1990	Project: DOUGLAS AIRCRAFT CO.	Fig A-26



WCC-8S: COOPER-JACOB PLOT			
Project No.: 8941863J	Date: MARCH 1990	Project: DOUGLAS AIRCRAFT CO.	Fig A-27

Woodward-Clyde Consultants

BOE-C6-0210579



DISTANCE/DRAWDOWN PLOT

Project No.: 8941863J	Date: MARCH 1990	Project: DOUGLAS AIRCRAFT CO	Fig A-28

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APPENDIX A

FIELD PROCEDURES
AND
AQUIFER TESTING DATA ANALYSIS

(2L-ABC/C6GW3-AA)

APPENDIX A

FIELD PROCEDURES AND AQUIFER TESTING DATA ANALYSIS

A.1 GENERAL INFORMATION

Drilling was performed by two companies: A&R Drilling, Inc. of Carson; and Beylik Drilling, Inc. of La Habra California. Drilling began on 5 June 1989 and was completed on 30 June 1989. Soil sample borings and shallow observation well borings were drilled using a CME-75 drill rig equipped with 6-1/2 inch O.D. hollow stem augers for soil sampling and 11-inch O.D. hollow stem augers for well installation. The deep observation well borings were completed by mud rotary drilling using an Ingersoll-Rand drill rig equipped with a 10-inch tri-cone drill bit.

A.1.1 Shallow Observation Well Installation

Observation Wells WCC-7S, 8S, and 10S were constructed of threaded 4-inch diameter, Schedule 40 PVC casing and screen and set to a depth of approximately 90 feet. The observation wells were installed by first drilling a sampling borehole with the 6-1/2-inch outside diameter (O.D.) hollow stem augers. In general, soil samples were collected at near-surface, 5 feet and then at approximately 5 foot intervals. Next, these augers were removed from the boring and the 11-inch O.D. hollow stem augers with a wooden plug placed in the bottom were used to ream out the boring to its total depth of 90 feet. Upon reaching total depth the inside of the augers were quickly filled with tap water and the wooden plug was knocked out of the bottom auger. The water was used to form hydrostatic pressure in the augers to help hold out the surging sands which would otherwise fill up the inside of the bottom augers and prevent a proper well installation. After knocking out the wooden plug, the 4-inch diameter wells were installed by inserting the casing into the hollow stem auger and allowing the well casing to rest on the bottom of the boring. Filter pack material (Lone Star No. 0/30) was poured from the surface into the annulus between the casing and hollow stem auger. As filter pack material was introduced into the borehole, the hollow stem augers were slowly withdrawn from the hole to allow the filter pack to fall in place between the well casing and native soil. The same procedure was followed in placing the bentonite plug and the volclay grout backfilling.

A.1.2 Deep Observation Well Installation

Observation Wells WCC-1D and WCC-3D were also constructed of threaded 4-inch diameter, Schedule 40 PVC casing and screen and set to a depth of approximately 140 feet. The wells were installed by first completing a sampling borehole using a wire line coring system which was used to attempt continuous coring from 120 to 140 feet. This sampling system worked satisfactorily on WCC-3D, but had little success in WCC-1D. After completing the sampling borehole, the geologic formation was electrically logged (E-logged) by Geo-Hydro-Data, Inc. of Tehachapi, California. Next, the boring was reamed out to the total depth with a 10-inch diameter drill bit.

Once the boring was completed for the casing installation, the drilling mud was thinned to help break down the mud cake formed on the sidewalls of the boring. In both WCC-1D and WCC-3D the mud was thinned too much on the first attempt, and the boring sidewalls caved in and had to be redrilled. The well casing was placed down the 10-inch boring with centralizers installed at five locations along its length to keep it centered in the boring and not laying against the sidewalls. Filter pack sand was placed outside the screened interval of the casing using 1-1/2 inch diameter tremie pipe and washing it down with tap water. A bentonite plug was set in the boring on top of the filter pack by pouring 1/4-inch bentonite pellets directly into the boring.

After allowing the bentonite pellets to settle into place the remainder of the annulus was backfilled by tremie pipe with volclay grout up to 8 feet below the surface. The top 8 feet of the annulus was backfilled with concrete.

A.1.3 Well Construction

The observation wells were constructed of 4-inch O.D. Schedule 40 PVC flush-threaded blank pipe, and screened with 0.010-inch slotted PVC screen. Adhesives were not used. The shallow wells were installed with 70 feet of blank casing and 30 feet of screen. The deep wells were installed with 120 feet of blank casing and 20 feet of screen. The well screen was filter packed by pouring or treming the filter material into the borehole from the surface. A filter pack material of Lone Star No. 0/30 sand was selected based on a field sieve analysis. Filter pack analysis and design procedures are discussed in Section C.4. The filter pack was placed from the well bottom to about 5 feet above the top of the well screen.

An approximately 5-foot thick bentonite pellet plug was placed on top of the filter pack, to minimize movement of fluids through the annular space. In addition, volclay bentonite grout was placed in the annulus from the top of the bentonite plug to approximately 8 feet below ground surface. A concrete plug was placed from the top of the volclay to the surface, to minimize seepage of surface fluids into the well and to provide strength to the backfill. The top of the well casings were completed 3 to 6 inches below grade with a waterproof locking well cap and protected with a moisture resistant steel traffic-rated

Christy box. Figure A.0 is a schematic of the general observation well design. Appendix D presents the boring logs and graphic well construction details.

A.1.4 Soil Borings

Four soil borings, B-6 through B-9, to collect soil samples for chemical analysis and lithologic logging, were completed in the vicinity of the underground tank cluster, 15T through 18T. Each boring was completed to a depth of 65 feet.

Soil sampling as described in Section A.2 was completed in each boring just below the surface, and at 5-foot intervals to the total depth of each boring.

A.1.5 Soil Boring Backfill

Soil borings B-6 through B-9 were backfilled with silica sand and bentonite powder, at a ratio of 4 to 1. The top 1 to 2 feet of the borings were backfilled with asphalt.

A.2 SOIL SAMPLING

Soil samples were collected at 5-foot intervals in the soil borings and the shallow well borings to make observations regarding subsurface stratigraphic conditions and the presence of contamination, to perform field headspace tests, and to conduct laboratory analyses. Soil samples were collected using a modified California sampler that contained four brass tubes. The brass tubes were filled by driving the sampler 18 inches into undisturbed soil with the drop hammer. The number of blows required to drive the sampler 12 inches was recorded on the boring log and used to evaluate the density or consistency of the soil.

Additional soil sampling was completed for logging purposes only in the deep well borings beginning at 120 foot depth and continuing to 140 feet. This sampling was performed using a wire line coring system which had a 2-inch diameter by 5-foot long split barrel sampler.

A.2.1 OVA Headspace Measurements

In general, one brass tube from each sample was extruded and placed into a sealable plastic bag. The bag was sealed and after approximately 5 to 10 minutes, an organic vapor analyzer (OVA) probe was inserted into the bag, and the vapor concentration in the headspace was measured and recorded on the boring log.

A.2.2 Soil Sample Preparation

One to two tubes from the soil sampler were prepared for laboratory analysis. The ends of the tubes were covered with aluminum foil, plastic end caps, and sealed with electrical tape. Soil samples were labeled with the following information:

- Project number
- Project name
- Boring number
- Sample number
- Soil depth
- Date
- Sampler's initials

The soil samples were then sealed in Ziploc plastic bags and placed on ice in an ice chest. All of the soil samples were delivered to West Coast Analytical Service, Inc. in Santa Fe Springs, California for analysis. Chain-of-custody procedures, including the use of sample identification labels and chain-of-custody forms were used for tracking the collection and shipment of soil samples. Copies of the chain-of-custody forms are presented in Appendix C.

A.2.3 Drilling Residuals

Drill cuttings from the soil borings and the shallow well borings were placed in Department of Transportation (DOT) Class 17H 55-gallon drums, and the contents of the drums were labeled using a permanent ink marker and a spray-painted inventory number corresponding to an inventory list compiled by the field engineer. The drums were sealed and stored inside the facility hazardous waste storage area. Drilling mud and soil cuttings produced during installation of the two deep observation wells were pumped into separate roll-off bins next to the wells. Douglas Aircraft was advised of the locations and contents of the drums, and the need for proper management of the drill cuttings.

A.3 FIELD OBSERVATIONS

Observations by Woodward-Clyde Consultants' personnel during the drilling, sampling, and well installation operations were recorded on boring logs, as presented in Appendix B. These observations related to visual soil classifications, geologic and stratigraphic sample descriptions, observation well construction details, sampling efforts, OVA measurements, and other pertinent information.

A.4 FILTER PACK ANALYSIS

The selection of the proper filter pack material and well screen slot size is essential in collecting a sediment-free or low sediment content water sample. In all observation wells, soil samples were collected for sieve analysis. Filter pack design calculations were made based on the grain size distribution of these finest grained soil samples collected within the designed screen interval and below the ground water table. For observation Wells WCC-1D, 3D, 7S, 8S, and 10S the depths of the samples analyzed were 123, 122, 75, 75, and 80 feet, respectively.

Soil sieve analyses for selection of well screen slot and filter pack size were conducted in the field. Each soil sample was heated with a portable propane stove to evaporate water from the soil. When the sample was dry, it was weighed on a scale to the nearest gram. The soil sample was then poured into the top of an eight sieve stack and shaken for approximately 5 minutes. The sieve sizes used in the analysis are shown in Figure A-1. The soil retained in each sieve was weighed and the cumulative percent retained was calculated for each sieve. The gradation analyses for the wells are illustrated in Figures A-1 through A-5.

A well design using a Lonestar No. 30 sand filter pack and a screen slot width of 0.01 inches (10 slot) was used for the five wells based on the gradation analyses. An ideal gradation of filter pack and screen slot width are plotted on Figures A-1 through A-5 along with the actual material sizes used. These ideal sizes were calculated using the well design formulas presented in "Ground Water and Wells" by Driscoll, 1986." A commercially blended filter pack material was then selected that best matched the calculated filter pack curve, since custom made filter pack materials were not readily available. The grain size analysis curves for Wells -1D, -3D, -7S, -8S, and -10S were similar, and the soils were classified as silty sands to sandy silts. This lithologic classification also correlated with the field descriptions of WCC--1D, -3D, -1S, -2S, -3S, and -4S.

A.5 WELL DEVELOPMENT

Observation Wells WCC-7S, -8S, -10S, -1D, and -3D were developed by Howard Pumps, Inc. of Barstow, California. Development occurred on 5 through 7 July 1989. During this development WCC-1D was damaged by breaking the bottom plug out of the well while bailing. Due to the formation conditions, sand surged up about 8 feet into the casing. This damage was repaired on 20 July 1989 by filling the well casing with drilling mud and then bailing the sand out of the bottom. Then a 2-foot plug of bentonite clay was set in the bottom of the well by pouring dehydrated bentonite pellets down the well and allowing them to hydrate. Once the pellets had hydrated, and formed a new bottom plug, the well was redeveloped.

All of the wells were developed, first by bailing and surging, to remove the maximum amount of sediment possible. Next the wells were pumped by submersible pump to remove a large volume of water and assure the ground water around the well was formation water which had not been affected by the well installation. The two deep observation wells, WCC-1D and -3D, required a greater effort in their development because they were installed using mud rotary drilling. In Table A-1 the development times, and the ground water volumes removed during development are presented. The water removed from each well was observed to become clearer during development and was completely clear upon completion of development. Water removed from the wells during development was stored in one large, steel, temporary "Baker" storage tank on site near Building No. 41, prior to treatment and discharge.

A.6 GROUND WATER SAMPLING

Two rounds of ground water sampling were completed from all ten of the observation wells. On 11, 12, 24, and 25 July 1989 the first round of sampling occurred (the two deep observation wells were sampled on the later two dates due to the damage of WCC-1D), and on 21 through 23 August 1989 the second round of sampling was completed.

Prior to beginning sampling procedures the static ground water level was measured in each well to the nearest one hundredth of a foot using an electronic well sounder. Then each well was purged, to remove possible stagnant water, by evacuating a minimum of three casing volumes of ground water. This was accomplished by bailing the well with a 3-1/2-inch-diamter PVC bailer attached to new polypropylene rope. The exception to this was the purging of WCA-1D and -3D on the first round of sampling only. These wells were purged by setting a submersible pump in the well and pumping a large volume of water for a final effort in development.

Throughout purging, and just prior to sampling the wells, pH, electrical conductivity or total dissolved solids, and temperature were measured and recorded for the evacuated ground water (Table A-2). These measurements were made to confirm that the wells were purged sufficiently. Sampling was done with a 1-1/2-inch-diameter Teflon bailer suspended from a monofilament line. Water samples were collected from each well in two 40 ml VOA vials.

In addition to water samples, bailer rinse samples were also collected in two 40 ml VOA vials for each well prior to collecting the water samples. The rinse samples were collected for possible analysis to confirm the sampling equipment was satisfactorily decontaminated.

The water samples, rinse samples, and two 40 ml VOA trip blanks for each sampling round, were packed on ice in a portable chest immediately after collection. Samples were delivered on the day following collection to West Coast Analytical Services. Chain-of-custody procedures, including the use of sample identification labels and chain-of-custody form, were used for tracking the collection and delivery of the samples. The chain-of-custody form is presented in Appendix C.

A.7 EQUIPMENT DECONTAMINATION PROCEDURES

Soil and ground water sampling equipment was decontaminated between sampling events using the following procedure:

1. Brush-assisted water rinse to remove soil and mud (soil sampling only)
2. Water wash with Liquinox
3. Deionized water rinse to remove Liquinox
4. Second rinse with deionized water
5. Dry with paper towels (soil sampling only).

Prior to use at the site, the brass tubes used in the modified California sampler were cleaned in WCC's laboratory by washing sequentially in dilute sulfuric acid, Liquinox and water, and deionized water. The tubes were then air dried, and stored in sealable plastic bags prior to use at the site. New end caps were carried to the site in sealable plastic bags.

Drill augers or pipes, pumps, bailers, surge blocks, and cables were all steam cleaned prior to working on each boring or well. Steam cleaning was performed by the drilling companies on the facilities steam cleaning pad.

A.8 SLUG TESTING

Slug tests were conducted on observation Wells WCC-4S, -5S, -7S, -8S, -9S, -10S, -1D, and -3D on 19 July, 30 August, and 4 October 1989. Slug testing is a relatively quick and cost-effective method of measuring actual field hydraulic conductivity (K) values. Slug test derived hydraulic conductivity (K) values are not as accurate as aquifer pump test derived values, however, they are useful in preliminary calculations and in identifying large anomalies in hydraulic conductivity (K) values.

Slug tests only measure the average horizontal hydraulic conductivity (K) in the immediate vicinity of the well. In comparison a pump test stresses the aquifer at a greater radial distance, and as a result, a more representative hydraulic conductivity value (K) is obtained.

The slug tests were performed using the following equipment:

- DL-120-MCP Envirolabs data logger with a 25 psi pressure transducer
- One 3.25-inch diameter x 39-inch-long sand weighted mandrel with a 1.4 gallon volume
- Steel tripod and polyethylene rope

The weighted mandrel was used with the tripod and rope to simulate a slug of water being inserted and withdrawn from the well. The pressure transducer and data logger recorded the subsequent drawdown and recovery water level measurements of the well. One cycle of drawdown and recovery was performed on each observation well.

Data from the slug tests were evaluated using the Bouwer-Rice method (June 1976) for calculating hydraulic conductivity (K). Bouwer and Rice developed a procedure that considers the effects from partially penetrating wells, the radius of the gravel pack, and the effective radius of influence of the test.

The Bouwer and Rice method entails solving the following equation:

$$K = \frac{r_c^2 \ \ln(R_e/R_w)}{2Lt} \ \ln \ (Y_o/Y_t)$$

Where:

K = hydraulic conductivity

r_c = radius of well casing

R_e = effective radius of influence

r_w = radius of the well boring

L = length of screened interval or saturated thickness if entire screen is not saturated

t = arbitrarily selected time from drawdown/time semi-log plot

Y_o = initial drawdown at time t = 0, from drawdown/ time semi-log plot

Y_t = drawdown (distance between water level in well and static water level) at selected time (t) from drawdown/time semi-log plot

The term R_e/r_w, which is a function of the radius over which the drawdown in the well is dissipated, was solved using the following equation:

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{A + B\ln[(D-H)/r_w]}{L/r_w}\right]^{-1}$$

Where:

H = distance from base of well to Static Water Level (SWL)

L = length of screen (or saturated thickness if entire screen is not saturated)

D = thickness of aquifer

A = constant based on value of L/r_w

(see Figure A-22)

B = constant based on value of L/r_w

(see Figure A-22)

The test data were plotted on a semi-log diagram of drawdown (Y_t) versus time (t), drawdown being logarithmic (see Figures A-6 through A-21). The data should generate a straight line, although a flat "tail" is frequently observed. A drawdown (Y_t) is recorded for a selected time (t) within the straight line segment of the plot. Y_t and t are used in solving the equation for K.

The Bouwer and Rice method makes the following assumptions:

1. The aquifer is of constant thickness.
2. The soil is homogeneous and isotropic.
3. Flow is horizontal in the aquifer.

These assumptions are judged to be generally reasonable, recognizing that variations in aquifer thickness and anisotropic conditions will have an influence on calculated results.

A.9 PUMP TEST

The pumping well, WCC-4S, was selected because it is centrally located to the surrounding observation wells. In addition information collected during slug testing indicated the well would have a relatively high yield. Wells WCC-1S, -4S, -6S, -7S, -8S, -9S, and -1D served as observation wells.

Details of the well design for the existing ten shallow observation wells and the two deep observation wells are summarized in Table A-3. Depth of groundwater and distance to the pumping well is also included. Figure 2 shows the locations of the wells.

A 1-1/2 horsepower submersible pump was used to pump water from WCC-4S. The pump was switched on at 12:00 p.m. on 20 December 1989 and allowed to pump at 13.3 gpm for 16 hours and 30 minutes. At this rate the water level was nearly stable at a drawdown of approximately 6 feet.

The evacuated groundwater was stored in two 21,000-gallon transportable steel storage tanks. Storage requirements were estimated based on well development activities which indicated a maximum pumping rate of 4 to 5 gallons per minute. Assuming a pumping rate of up to 10 gallons per minute, Woodward-Clyde initially ordered one storage tank and figured if and when a second storage tank was required, it would be more than 24 hours after the pumping began. Because the pumping rate was greater than 10 gpm the second storage tank would have been needed before the tank rental company could respond to our request, if the 13.3 gpm pumping rate was sustained. Therefore, the flow rate was reduced to 8.5 gpm for 4-1/2 hours. After the second tank was delivered to the site, the flow rate of 13.3 was resumed and maintained for the remainder of 30 total hours of "pumping". The overall time weighted pumping rate was approximately 12.6 gal/min. The pump was switched off at 6:00 p.m. on 21 December 1989. Measurements in the pumping well and all the monitoring wells continued until WCC-4S had recovered 99 percent of its maximum drawdown, two hours after the pump was shut off.

Water was pumped to the surface and approximately 400 feet horizontally to the storage tanks. The volume of water pumped out of WCC-4S was measured by an in-line totalizer. A total of approximately 28,000 gallons of groundwater was evacuated.

Five of the monitoring wells WCC-4S, -1S, -7S, -8S, and -1D had pressure transducers installed and connected to one of three Terra 8 data loggers to automatically measure and record the depth to groundwater. In addition, Woodward-Clyde measured the depth to groundwater on regular intervals in all of the observation wells except WCC-1S, -4S, and -1D. This task was performed using a Solonist electric well sounder. In addition barometric pressure readings were collected at regular intervals throughout the pump test using a Swift, Model 477 barometer.

The data from each well showing a discernable reaction were analyzed using one or more of the following techniques: Recovery (Residual Drawdown) plot, Cooper-Jacob Time-Drawdown plot, and/or Distance/Drawdown plot. A summary of the results is previously presented in Table 2. Slug test values obtained earlier are included for reference.

The nearly instantaneous initial drawdown and the subsequent constant drawdown with time, precluded any valid analyses of the pumping stage drawdown in the pumping well WCC-4S.

Nevertheless the recovery data for the pumping well which did appear valid was analyzed using a residual drawdown plotting technique.

This technique utilizes a semi-log plot of the residual drawdown (in feet) vs. the ratio of t/t′ (see Figure A-23) where:

t = time since pumping started

t′ = time since pumping stopped

The differential change in water level (Δs) is thus obtained from the plot and used in the equation:

$$K = \frac{264Q}{\Delta s \cdot b} \qquad (1)$$

where:

K = Hydraulic conductivity in gpd/ft^2

Q = Pumping rate, in gpm

Δs = Differential change in water level during one log cycle of time, in feet

b = The aquifer thickness (20.65 feet at WCC-4S)

Data for the observation wells WCC-1S, -6S, -7S, and -8S were analyzed using the Cooper-Jacob Time-Drawdown technique as shown on Figures A-24 to A-27. A calculation of μ (from the well function, Driscoll 1986) showed the technique would be appropriate in general. A Distance/Drawdown plot shows the change in drawdown as a function of distance from the pumping well. The equations used and the calculations are shown with the plot. Analytical methods used are discussed in the literature (Driscoll, 1986; Walton, 1987). The fundamental equation for hydraulic conductivity is identical to Equation (1) above. Other equations include:

$$T = Kb \tag{2}$$

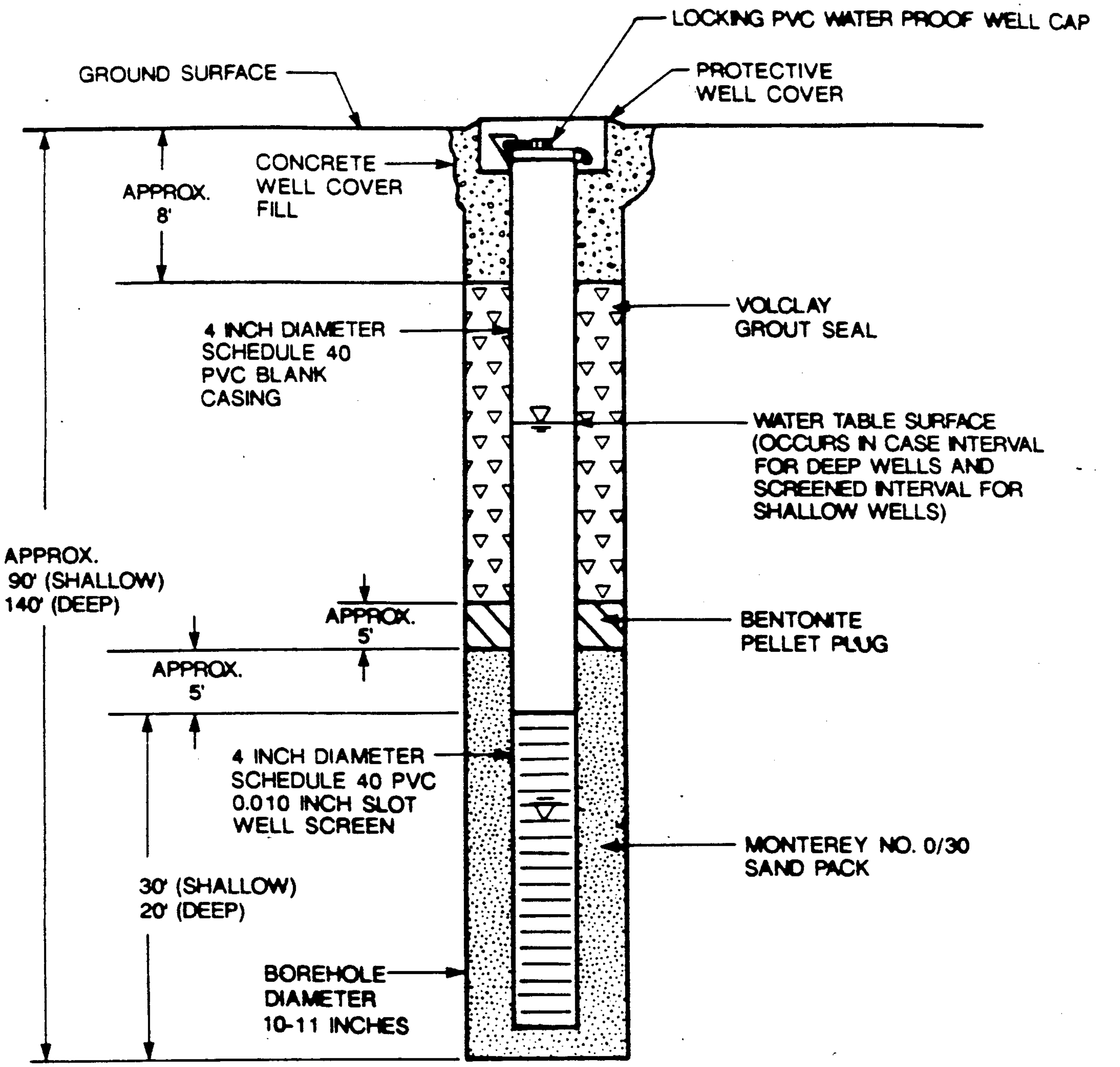
and

$$S = \frac{0.3Tt_o}{r^2} \tag{3}$$

where:

T	=	Coefficient of transmissivity, in gpd/ft
K	=	Hydraulic conductivity in gpd/ft^2 (Equation [1])
b	=	Saturated thickness of the aquifer tested in feet
s	=	Storage coefficient (dimensionless)
t_o	=	Time, in days, of the intercept of the extrapolated drawdown curve at zero drawdown
r	=	Distance, in feet, from pumped well to the observation well where drawdown measurements were made

These plots allowed the calculation of both hydraulic conductivity, and storage coefficient according to Equations (1) and (3). The method of plotting and the calculation are shown on Figure A-28.



NOT TO SCALE

DESIGN APPLIES TO
WCC-7s, -8s, -10s, -1D, AND -3D

SHALLOW WELL DEPTH 90 FEET
DEEP WELL DEPTH 140 FEET

GENERAL OBSERVATION WELL DESIGN

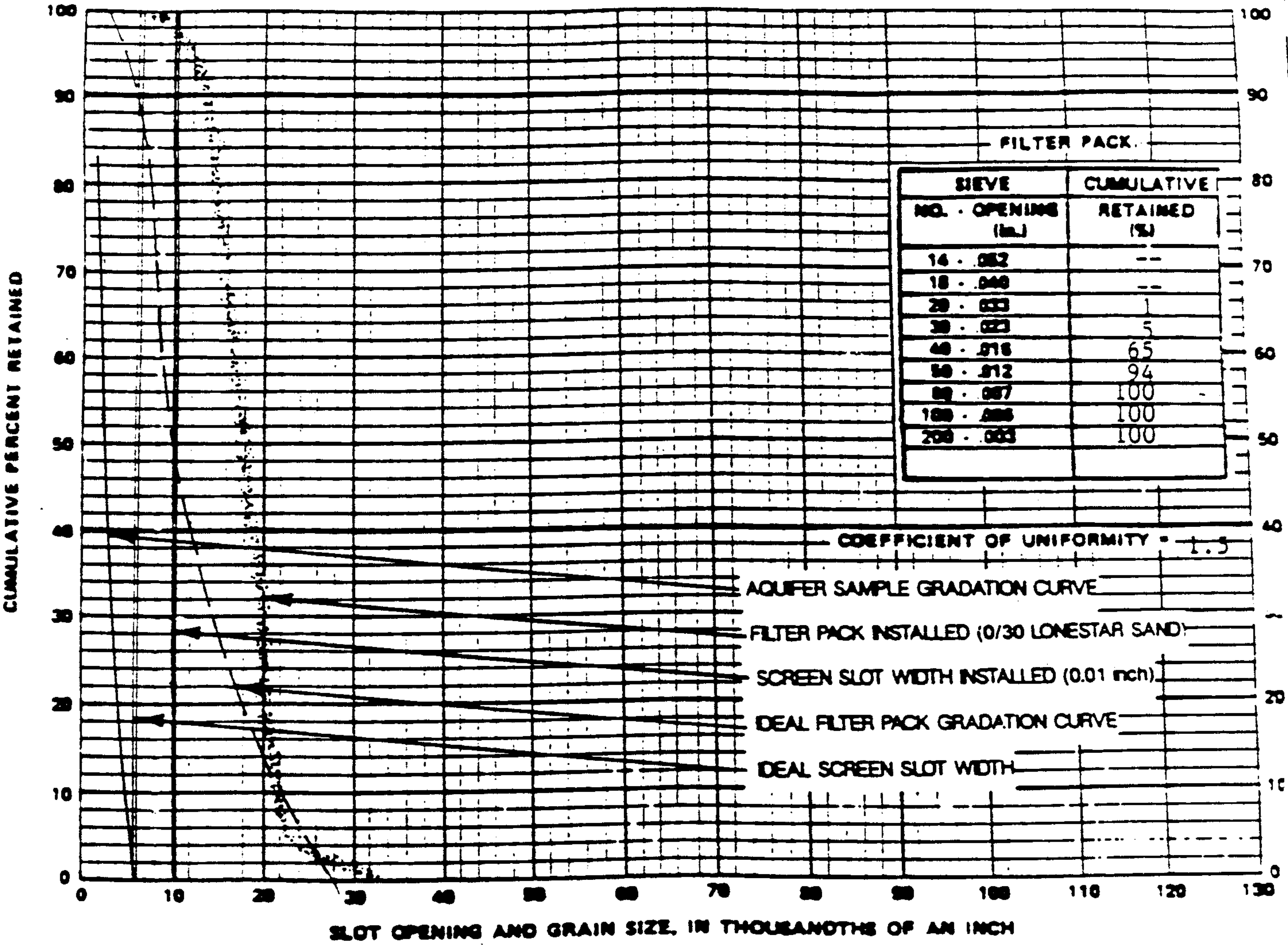
Project No.: 8941863J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT-C6 FACILITY	Fig. A.0

Well Name: WCC-7s **Date:** 3 June 1989

Well Location: 160 ft. South of WCC-4s

Sample Depth: 75 ft. **Performed By:** P.GLAESMAN/H. REYES

Comments:



FILTER PACK

SIEVE NO. - OPENING (in.)	CUMULATIVE RETAINED (%)
14 - .052	--
16 - .040	--
20 - .033	1
30 - .023	5
40 - .016	65
50 - .012	94
80 - .007	100
100 - .006	100
200 - .003	100

SIEVE NO. - OPENING (in.)	SAMPLE WEIGHT (gram)	CUMULATIVE PERCENT RETAINED (%)	CUMULATIVE PERCENT PASSING (%)
16 - 040	--	--	
20 - 033	--	--	
30 - 023	--	--	
40 - 016	--	--	
50 - 012	--	--	
60 - 0098	--	--	
80 - 007	--	--	
100 - 006	5	2.0	
200 - 003	124	46.0	
Bottom Pan	270	100.0	

Notes: WET WT. of sample: 350 gm
DRY WT. of sample: 270 gm

Recommended Slot Opening:

Project DOUGLAS AIRCRAFT CO. - TORRANCE Project No. 8941863J	GRAIN SIZE ANALYSIS WCC-7S	Fig. A.1

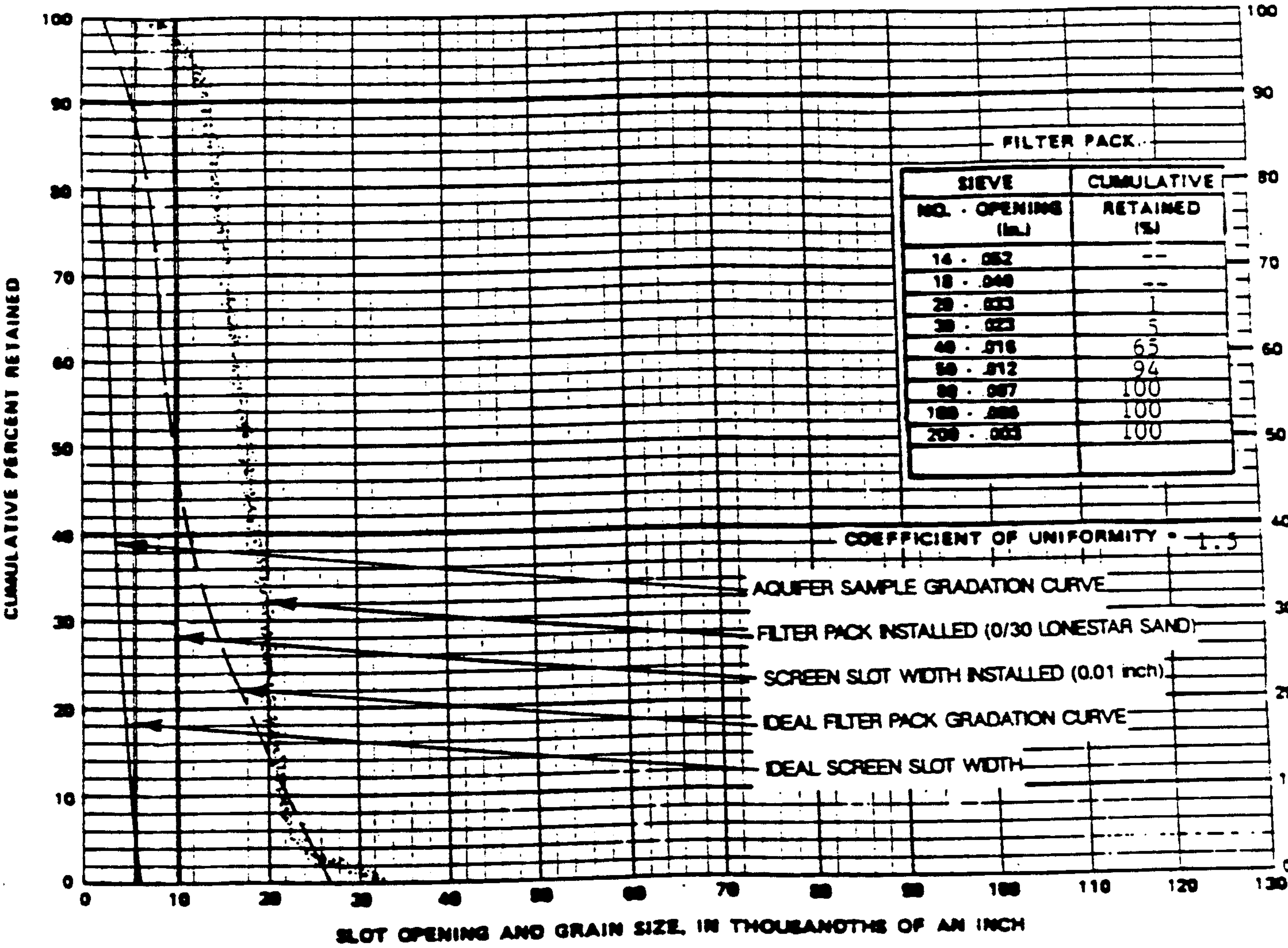
BOE-C6-0210600

Well Name: WCC-8s **Date:** 12 June 1989

Well Location: N125 ft. North of WCC-1s

Sample Depth: 75 ft. **Performed By:** P.GLAESMAN/H. REYES

Comments:



FILTER PACK

SIEVE NO. · OPENING (in.)	CUMULATIVE RETAINED (%)
14 · .052	--
18 · .040	--
20 · .033	1
30 · .023	5
40 · .016	65
50 · .012	94
80 · .007	100
100 · .006	100
200 · .003	100

SIEVE NO. · OPENING (in.)	SAMPLE WEIGHT (gms)	CUMULATIVE PERCENT RETAINED (%)	CUMULATIVE PERCENT PASSING (%)
18 · 040	--	--	
20 · 033	--	--	
30 · 023	--	--	
40 · 016	--	--	
50 · 012	--	--	
60 · 0098	--	--	
80 · 007	--	--	
100 · 006	3	1.0	
200 · 003	123	52.0	
Bottom Pan	235	100.0	

Notes: WET WT. of sample: 300 gm
DRY WT. of sample: 235 gm

Recommended Slot Opening:

Project DOUGLAS AIRCRAFT CO. - TORRANCE
Project No. 8941863J

GRAIN SIZE ANALYSIS WCC-8S

Fig. A.2

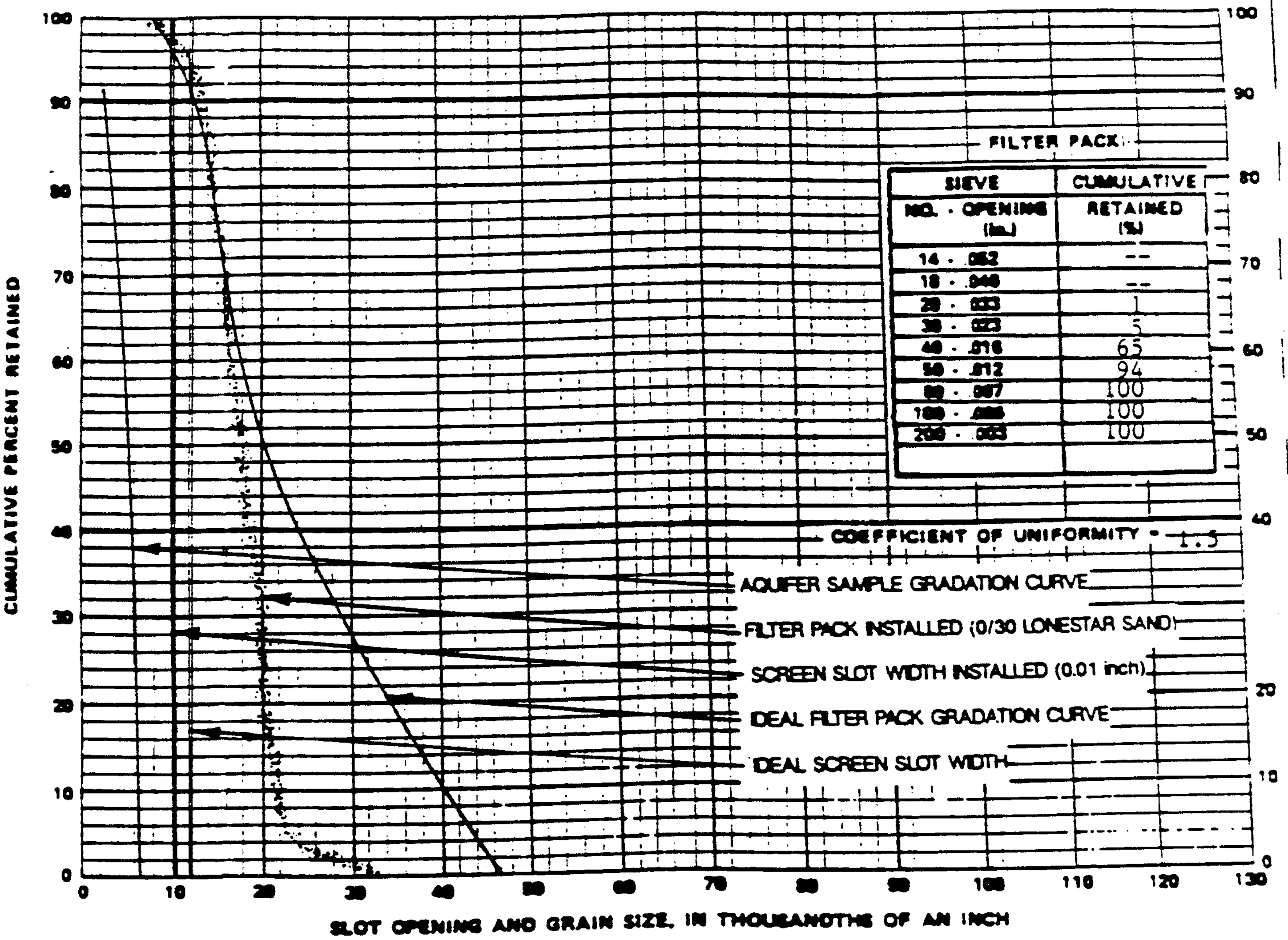
BOE-C6-0210601

Well Name: WCC-10S **Date:** 6 June 1989

Well Location: Northwest corner of property

Sample Depth: 80 ft. **Performed By:** P.GLAESMAN/H. REYES

Comments:



FILTER PACK

SIEVE NO. · OPENING (in.)	CUMULATIVE RETAINED (%)
14 · .052	--
18 · .040	--
20 · .033	1
30 · .023	5
40 · .016	65
50 · .012	94
60 · .007	100
100 · .006	100
200 · .003	100

SIEVE NO. · OPENING (in.)	SAMPLE WEIGHT (gms)	CUMULATIVE PERCENT RETAINED (%)	CUMULATIVE PERCENT PASSING (%)
18 · 040	--	--	
20 · 033	--	--	
30 · 023	--	--	
40 · 016	--	--	
50 · 012	--	--	
60 · 0098	--	--	
80 · 007	--	--	
100 · 006	157	35.0	
200 · 003	395	88.0	
Bottom Pan	450	100.0	

Notes: WET WT. of sample: 528 gm

DRY WT. of sample: 450 gm

Recommended Slot Opening:

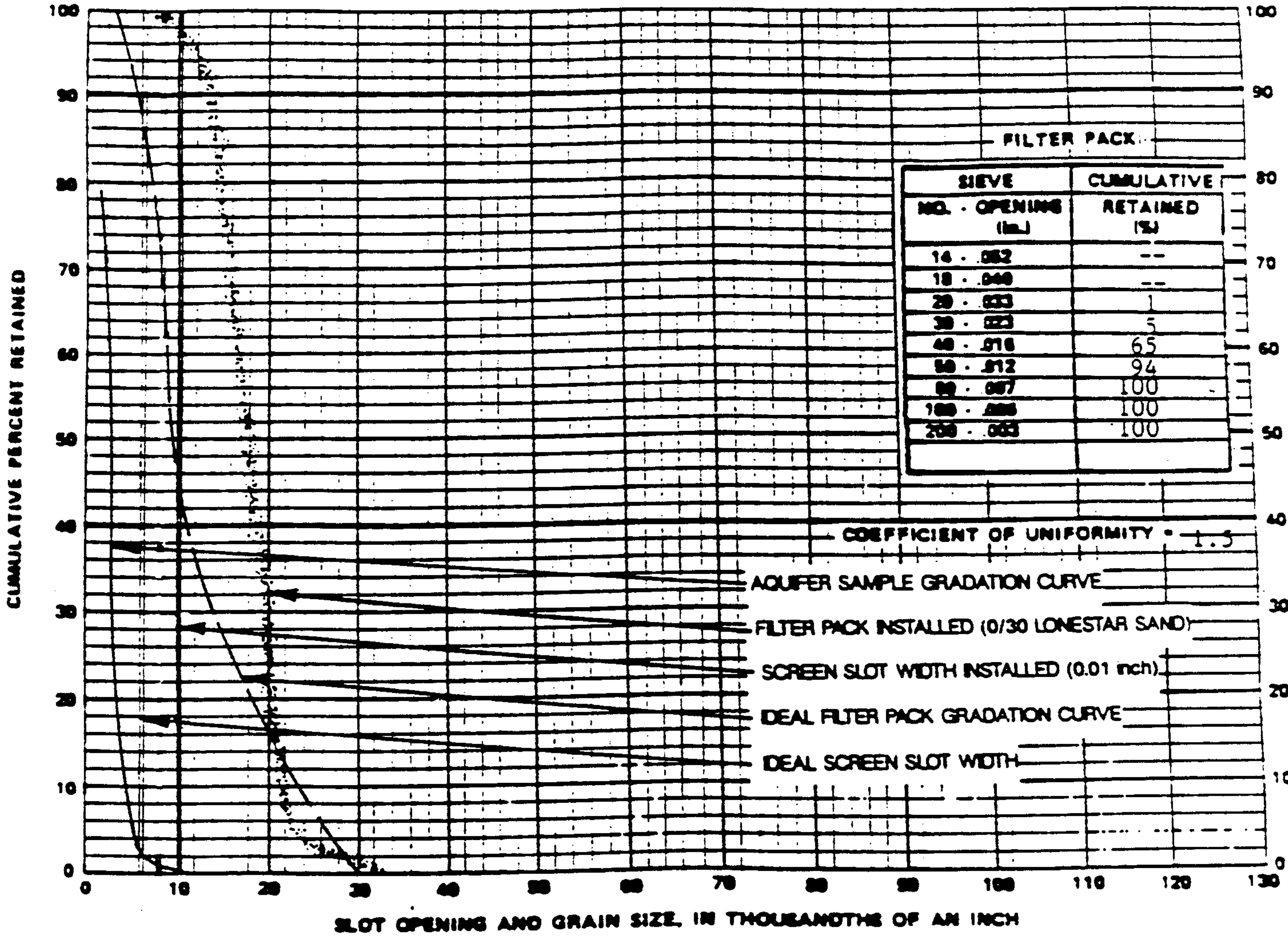
Project DOUGLAS AIRCRAFT CO. · TORRANCE Project No. 8941863J	GRAIN SIZE ANALYSIS WCC-10S	Fig. A.3

Well Name: WCC-1D **Date:** 6-29-89

Well Location: 10 feet south of WCC-1S

Sample Depth: 123 feet **Performed By:** P.GLAESMAN/H. REYES

Comments:



FILTER PACK

SIEVE NO. · OPENING (in.)	CUMULATIVE RETAINED (%)
14 · .052	--
18 · .040	--
20 · .033	1
30 · .023	5
40 · .016	65
50 · .012	94
80 · .007	100
100 · .006	100
200 · .003	100

SIEVE NO. · OPENING (in.)	SAMPLE WEIGHT (gms)	CUMULATIVE PERCENT RETAINED (%)	CUMULATIVE PERCENT PASSING (%)
18 · 040	--	--	
20 · 033	--	--	
30 · 023	--	--	
40 · 016	--	--	
50 · 012	2	0.8	
60 · 0098	2	0.8	
80 · 007	2	0.8	
100 · 006	8	3.1	
200 · 003	100	39.4	
Bottom Pan	254	100.0	

Notes: WET WT. of sample: 300 gm

DRY WT. of sample: 254 gm

Recommended Slot Opening:

Project DOUGLAS AIRCRAFT CO. - TORRANCE Project No. 8941863J	GRAIN SIZE ANALYSIS WCC-1D	Fig. A.4

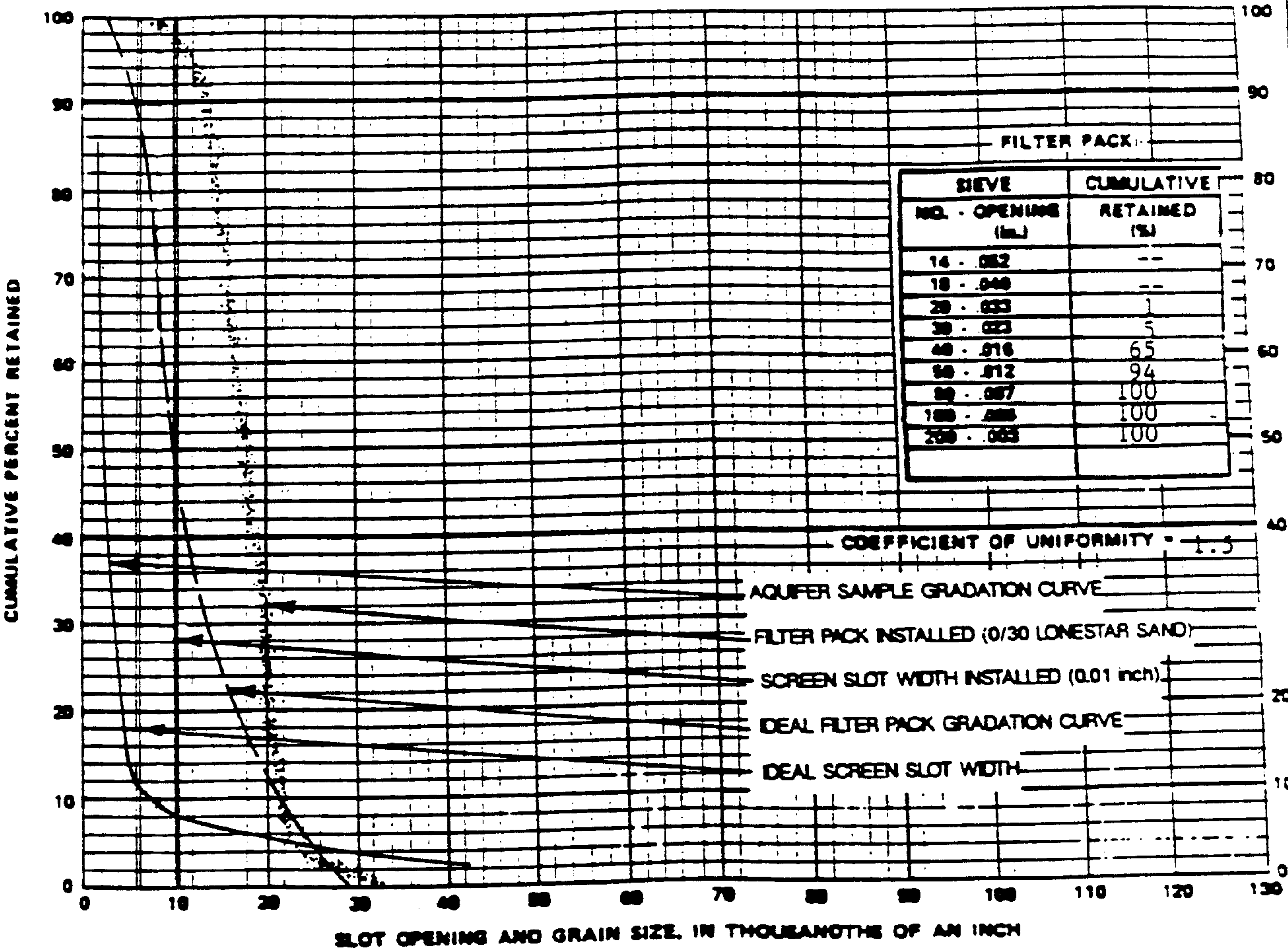
BOE-C6-0210603

Well Name: WCC-3D **Date:** 6-27-89

Well Location: 35 feet northwest of WCC-3S

Sample Depth: 122 feet **Performed By:** P.GLAESMAN/H. REYES

Comments:



FILTER PACK

SIEVE NO. - OPENING (in.)	CUMULATIVE RETAINED (%)
14 - .052	--
18 - .040	--
20 - .033	1
30 - .023	5
40 - .016	65
50 - .012	94
80 - .007	100
100 - .006	100
200 - .003	100

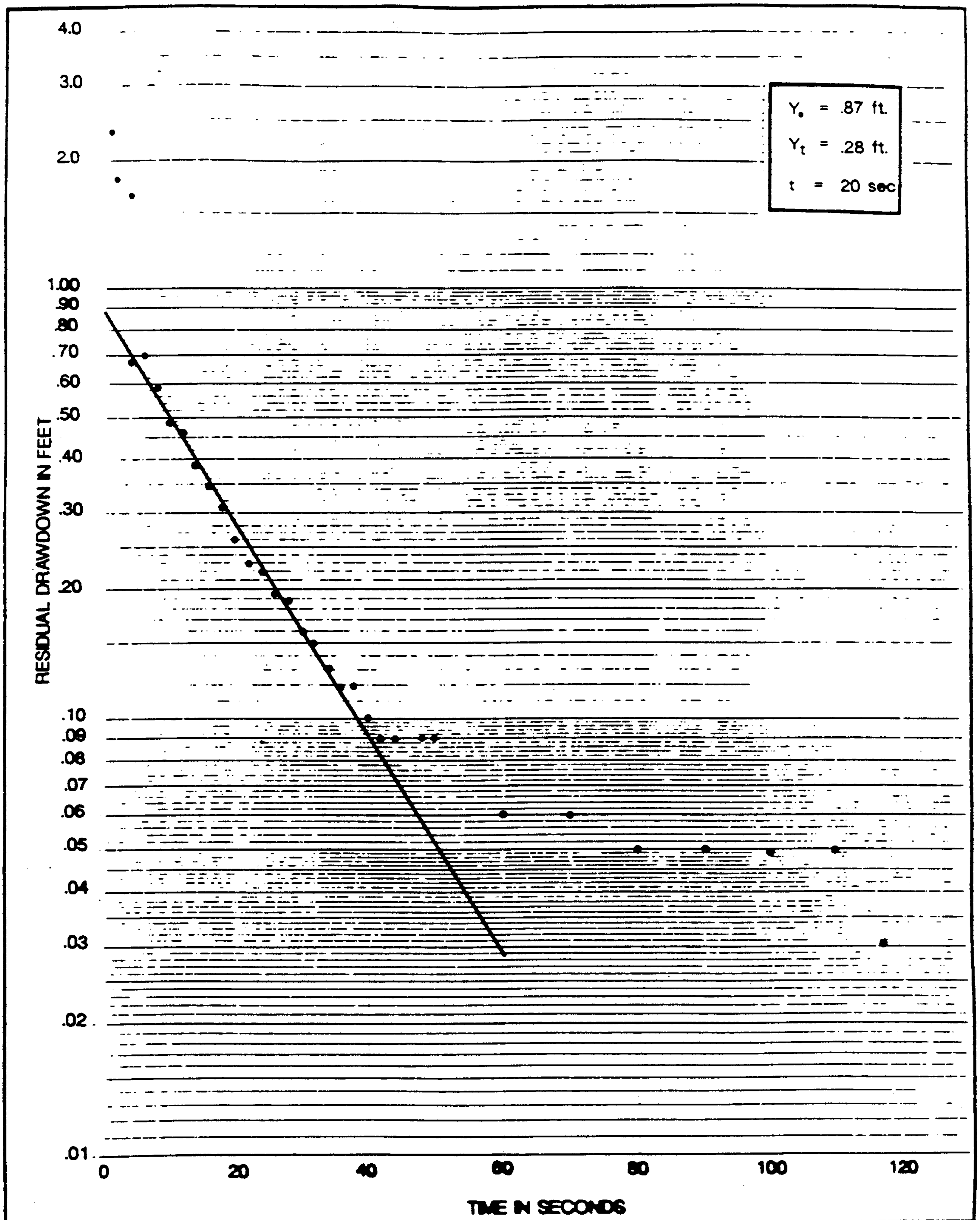
SIEVE NO. - OPENING (in.)	SAMPLE WEIGHT (grams)	CUMULATIVE PERCENT RETAINED (%)	CUMULATIVE PERCENT PASSING (%)
18 - .040	--	--	
20 - .033	9	3.6	
30 - .023	10	4.0	
40 - .016	12	4.8	
50 - .012	19	7.6	
60 - .0098	20	8.0	
80 - .007	22	8.8	
100 - .006	25	10.0	
200 - .003	122	48.8	
Bottom Pan	250	100.0	

Notes: WET WT. of sample: 300 gm

DRY WT. of sample: 250 gm

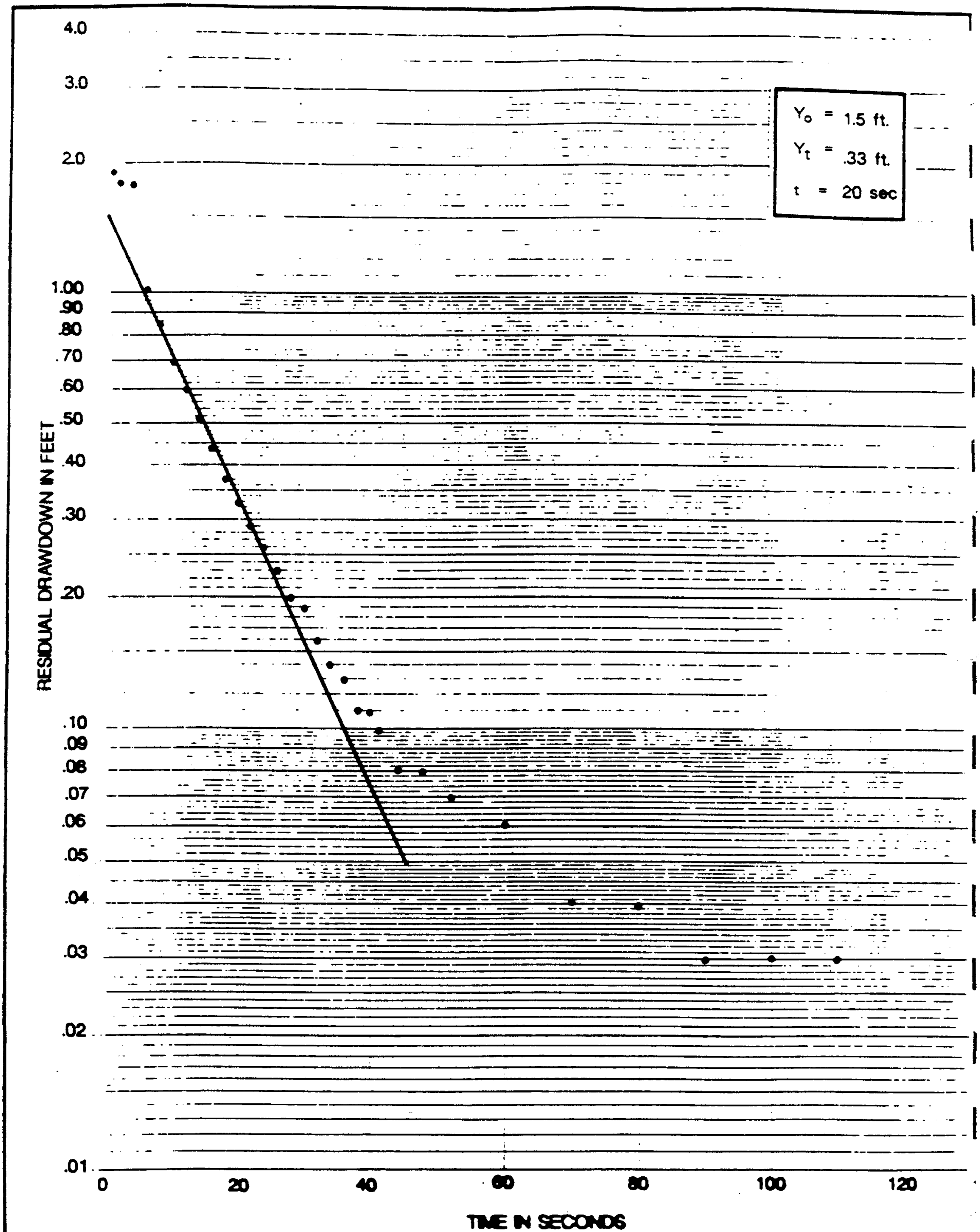
Recommended Slot Opening:

Project DOUGLAS AIRCRAFT CO. - TORRANCE Project No. 8941863J	GRAIN SIZE ANALYSIS WCC-3D	Fig. A.5



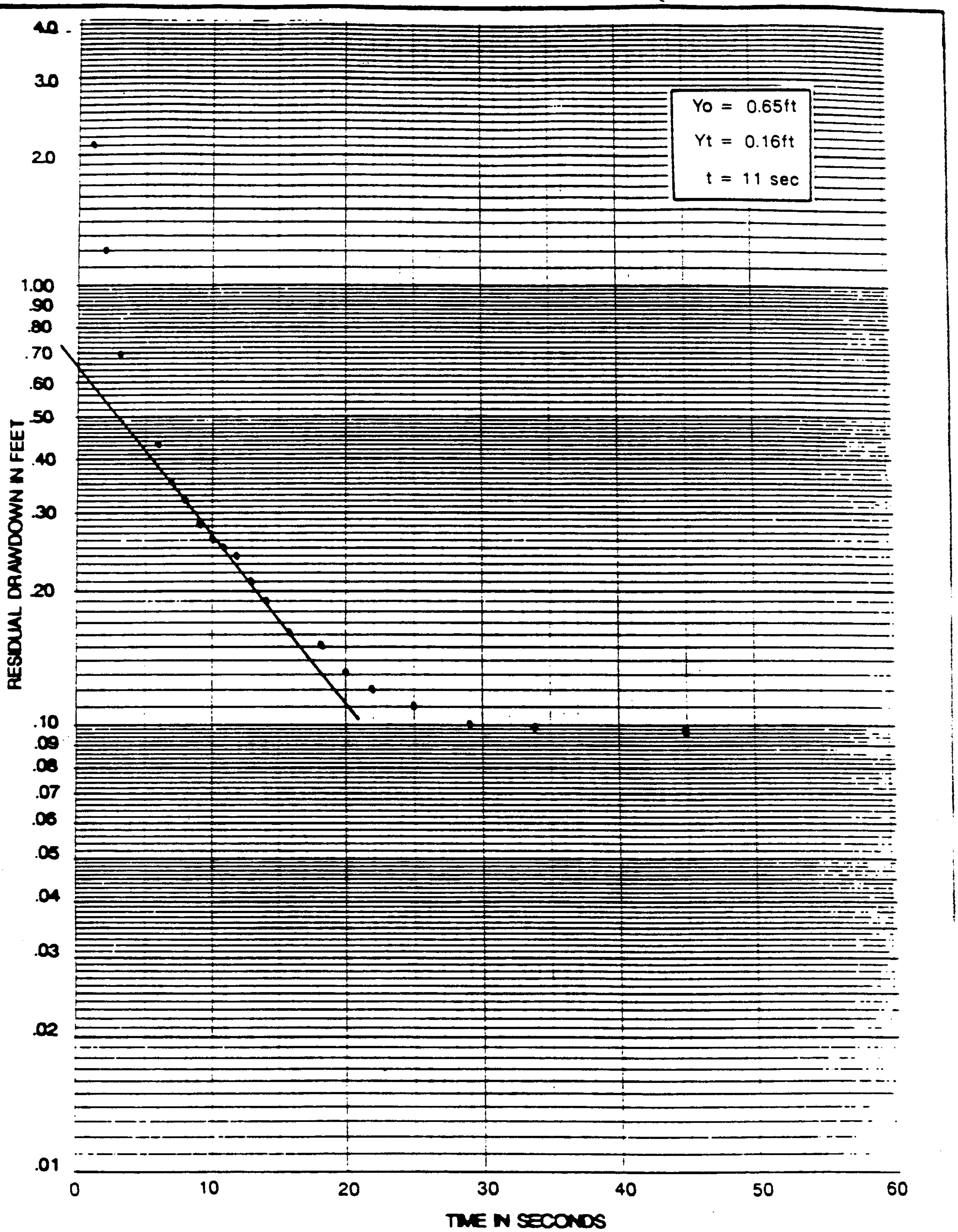
WCC-4S SLUG TEST INSERT

Project No.: 8041883J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.6



WCC-4S SLUG TEST WITHDRAWAL

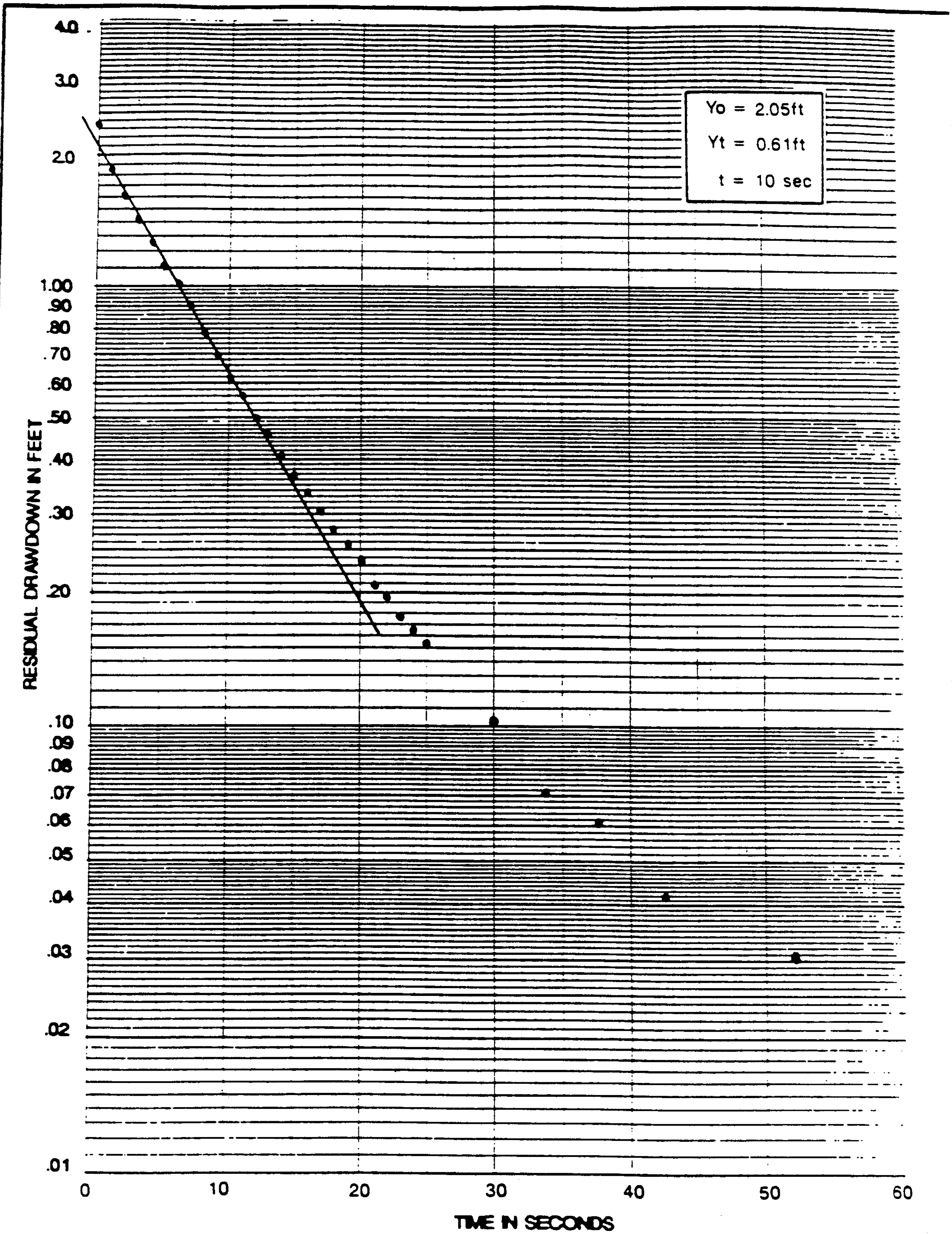
Project No.: [illegible]	Date: AUGUST [illegible]	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.7



WCC-5S SLUG TEST INSERT

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.8

Woodward-Clyde Consultants

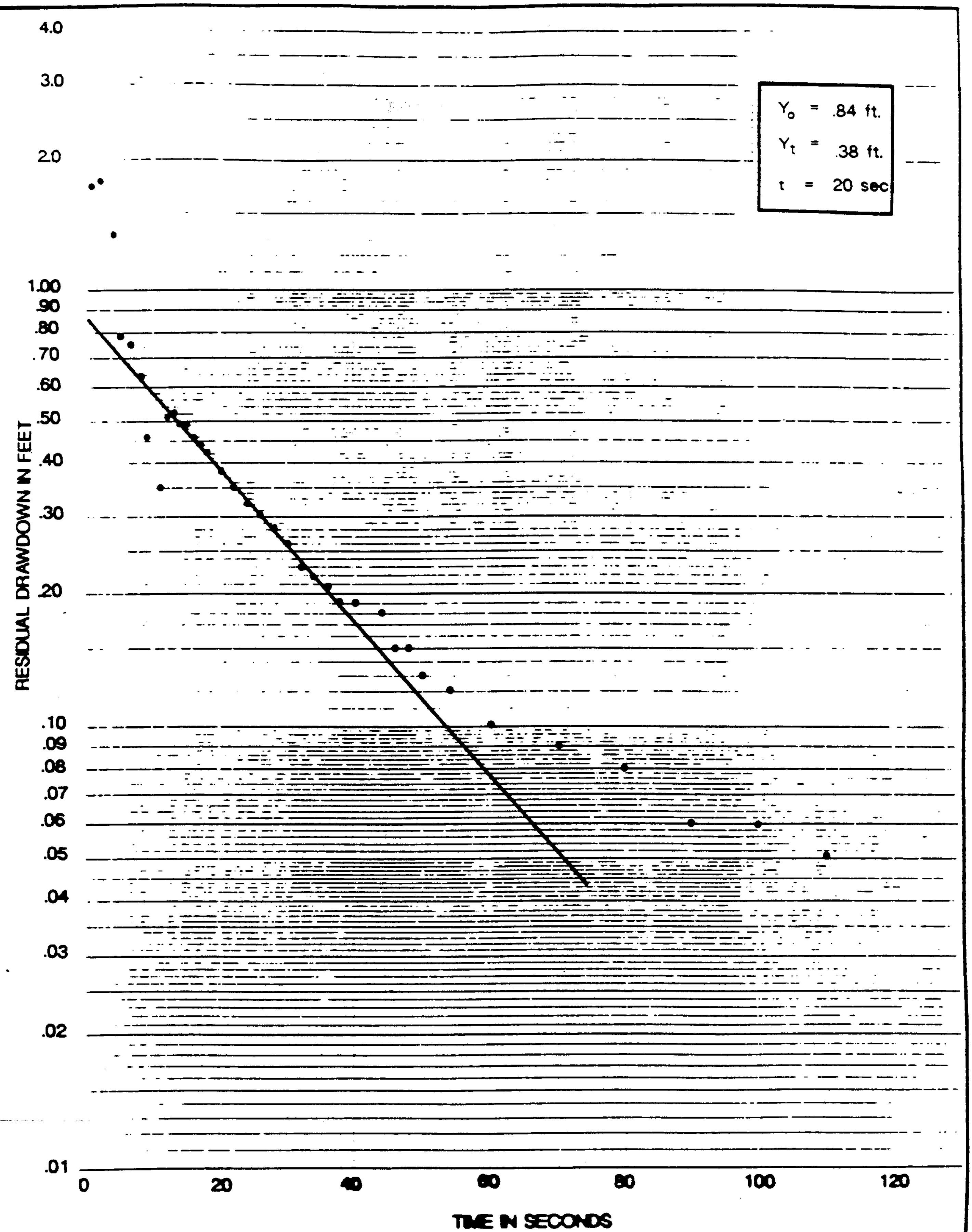


WCC-5S SLUG TEST WITHDRAWAL

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.9

Woodward-Clyde Consultants

BOE-C6-0210608



WCC-7S SLUG TEST INSERT

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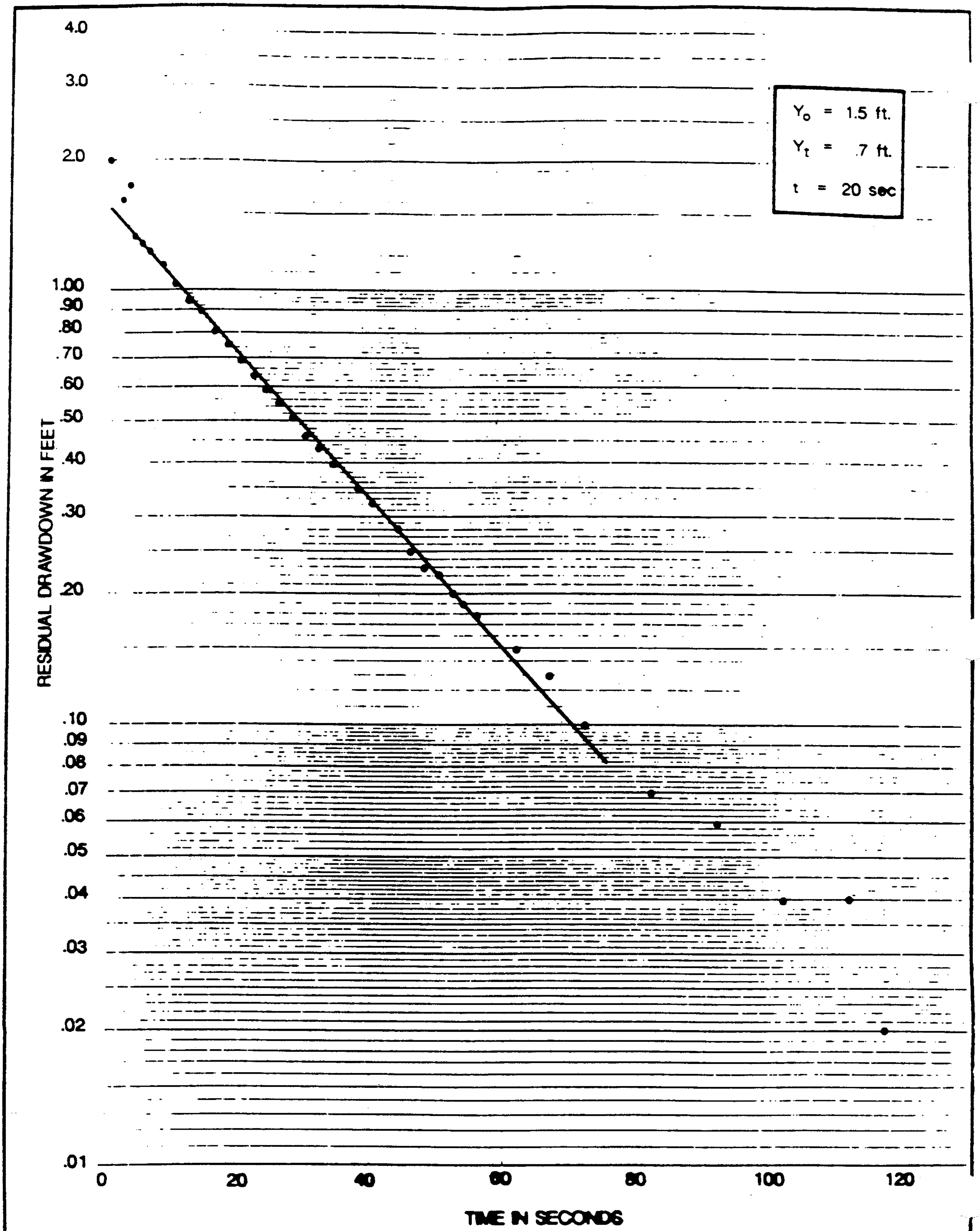
BOE-C6-0210609



WCC-7S SLUG TEST WITHDRAWAL

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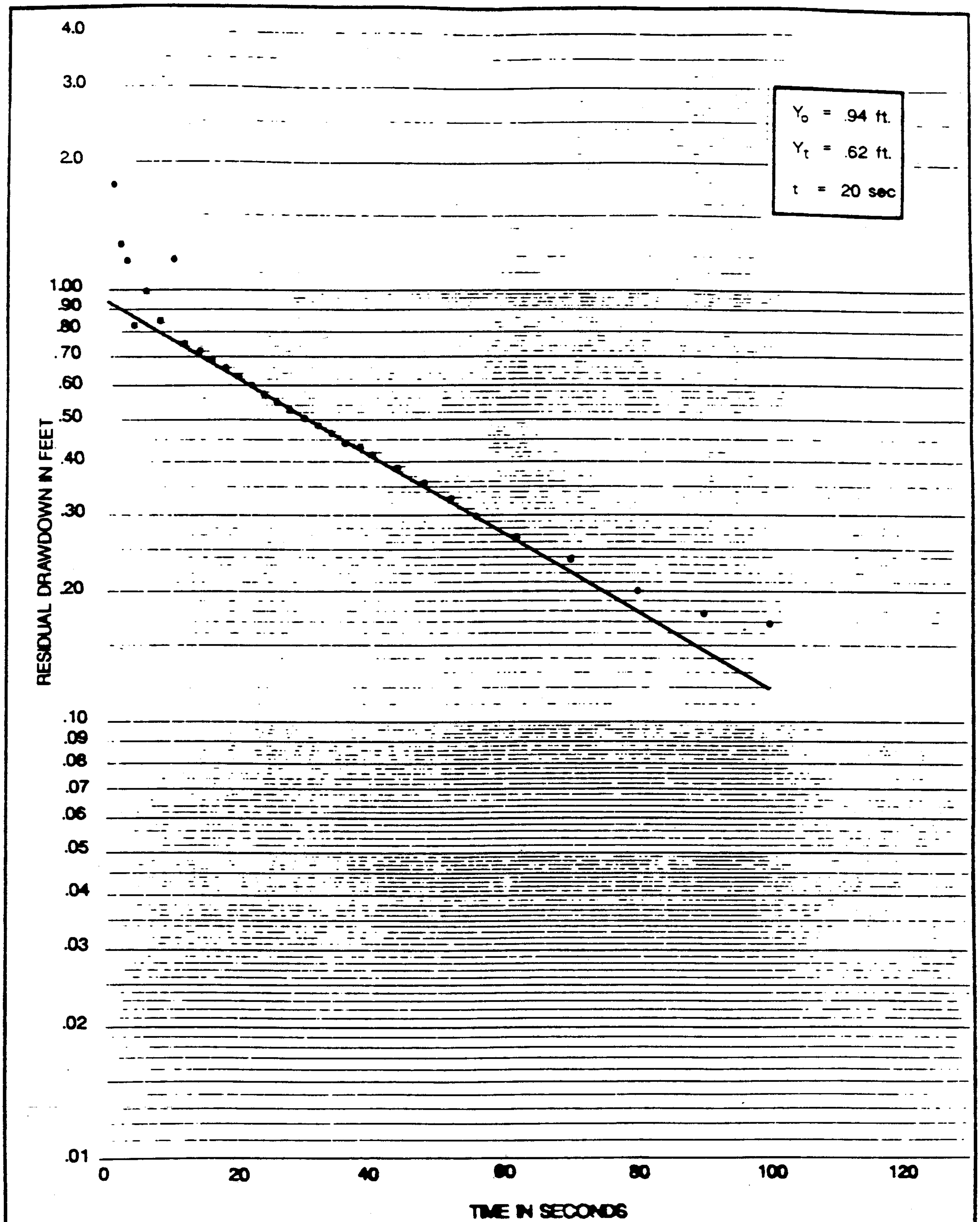
BOE-C6-0210610



WCC-8S SLUG TEST INSERT

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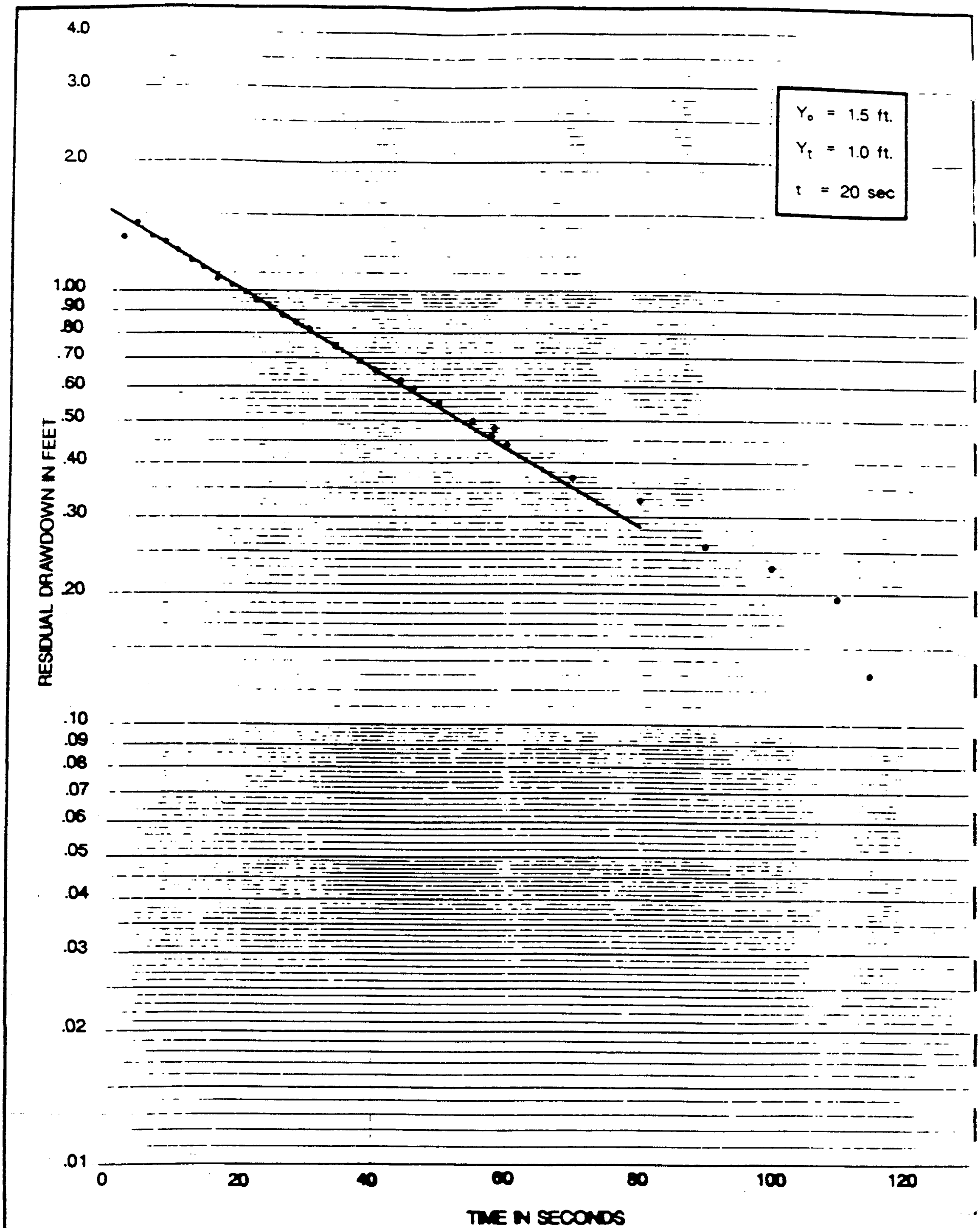
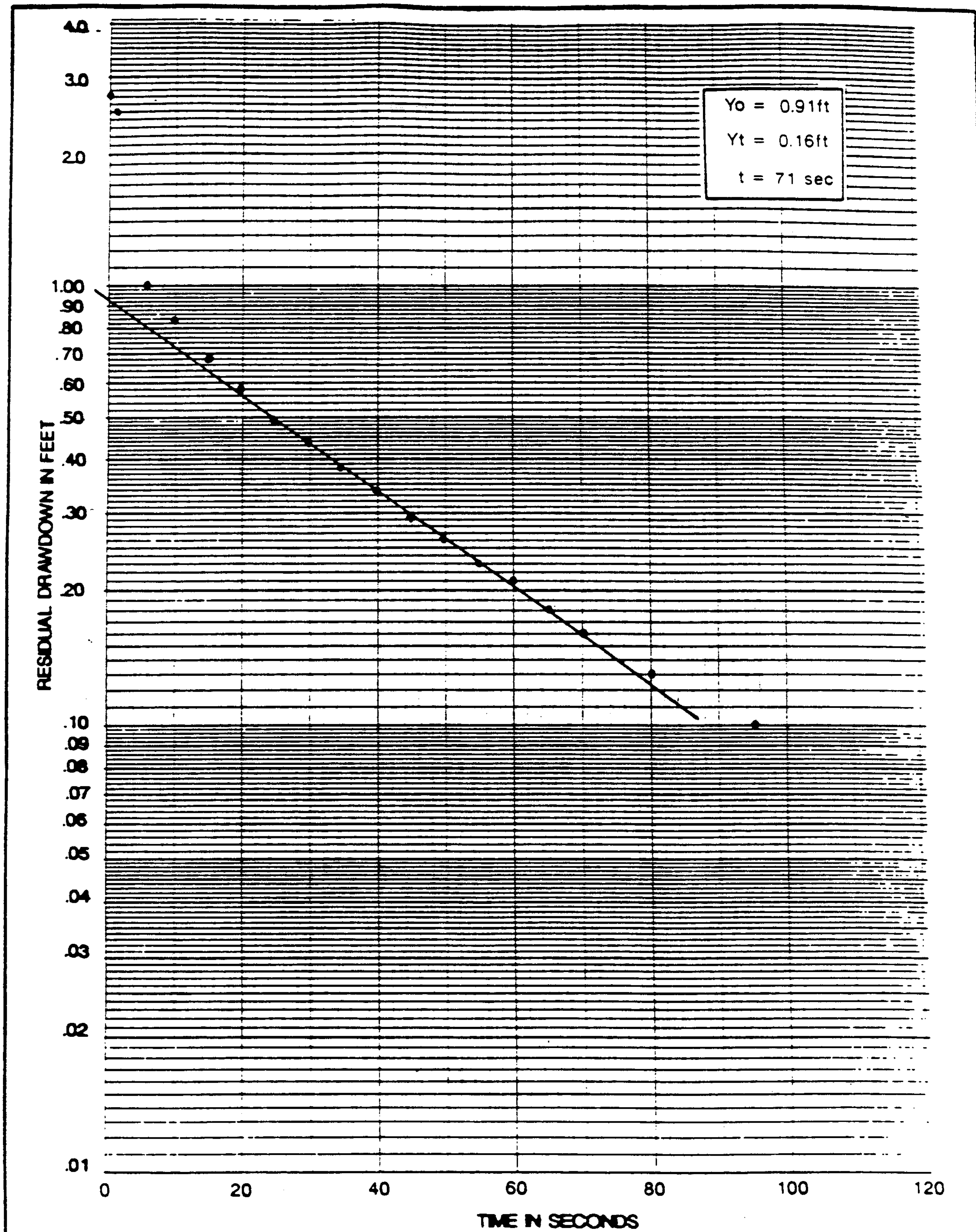


WCC-8S SLUG TEST WITHDRAWAL

Project No.: [illegible]	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.13

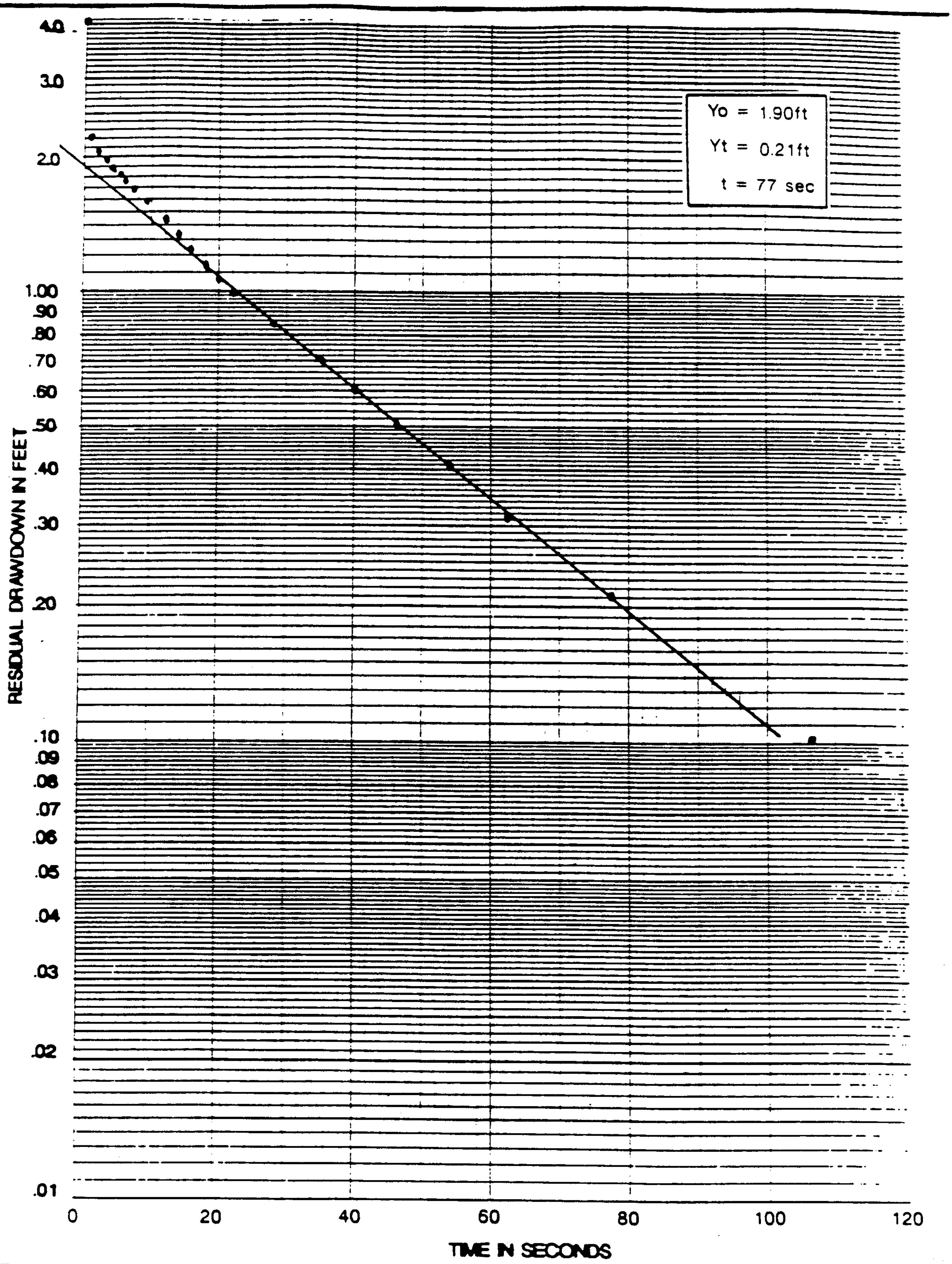


WCC-9S SLUG TEST INSERT

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.14

Woodward-Clyde Consultants

BOE-C6-0210613

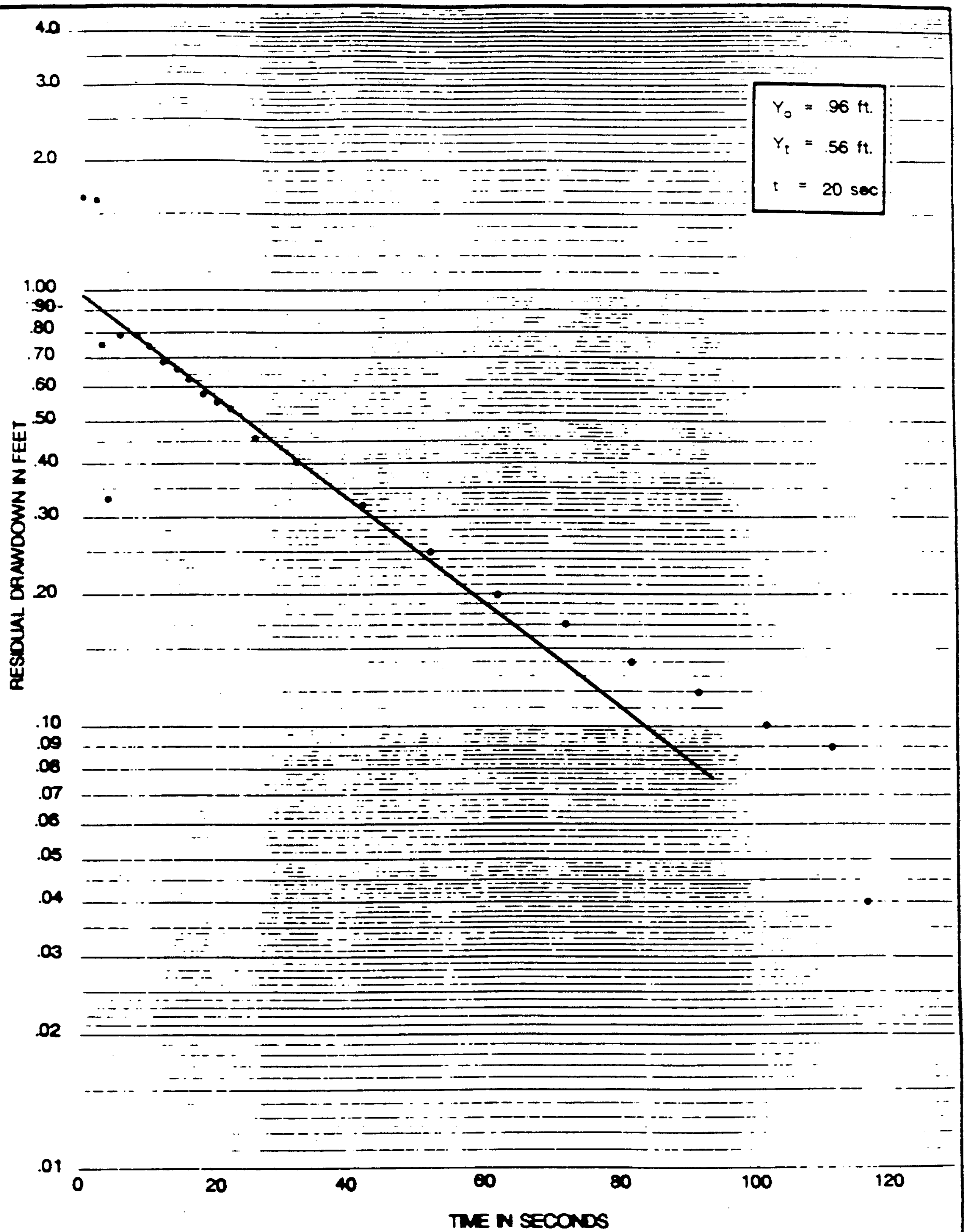


WCC-9S SLUG TEST WITHDRAWAL

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.15

Woodward-Clyde Consultants

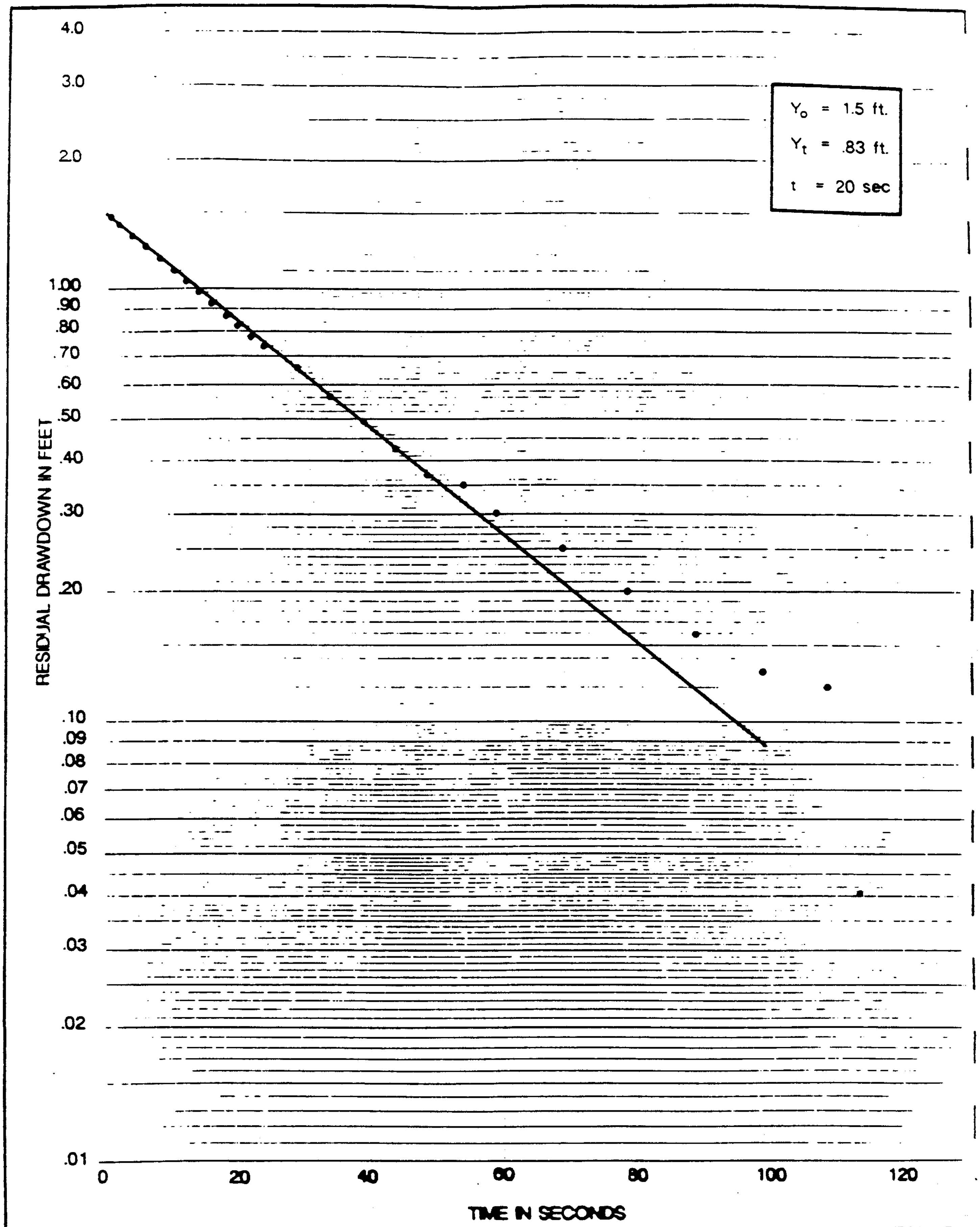
BOE-C6-0210614



WCC-10S SLUG TEST INSERT

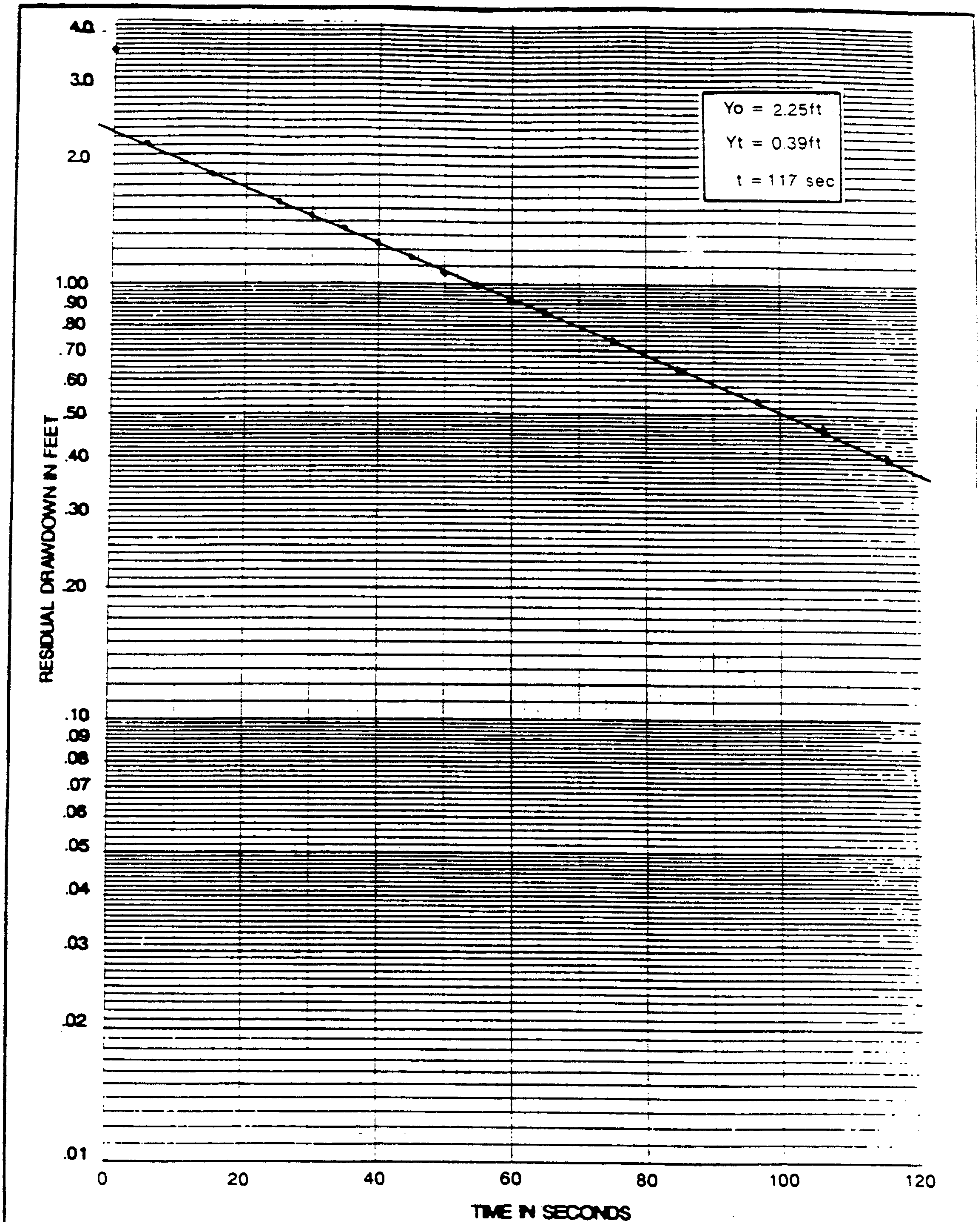
Project No.: 8941863J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.16

Woodward-Clyde Consultants



WCC-10S SLUG TEST WITHDRAWAL

Project No.: 8941863J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.17

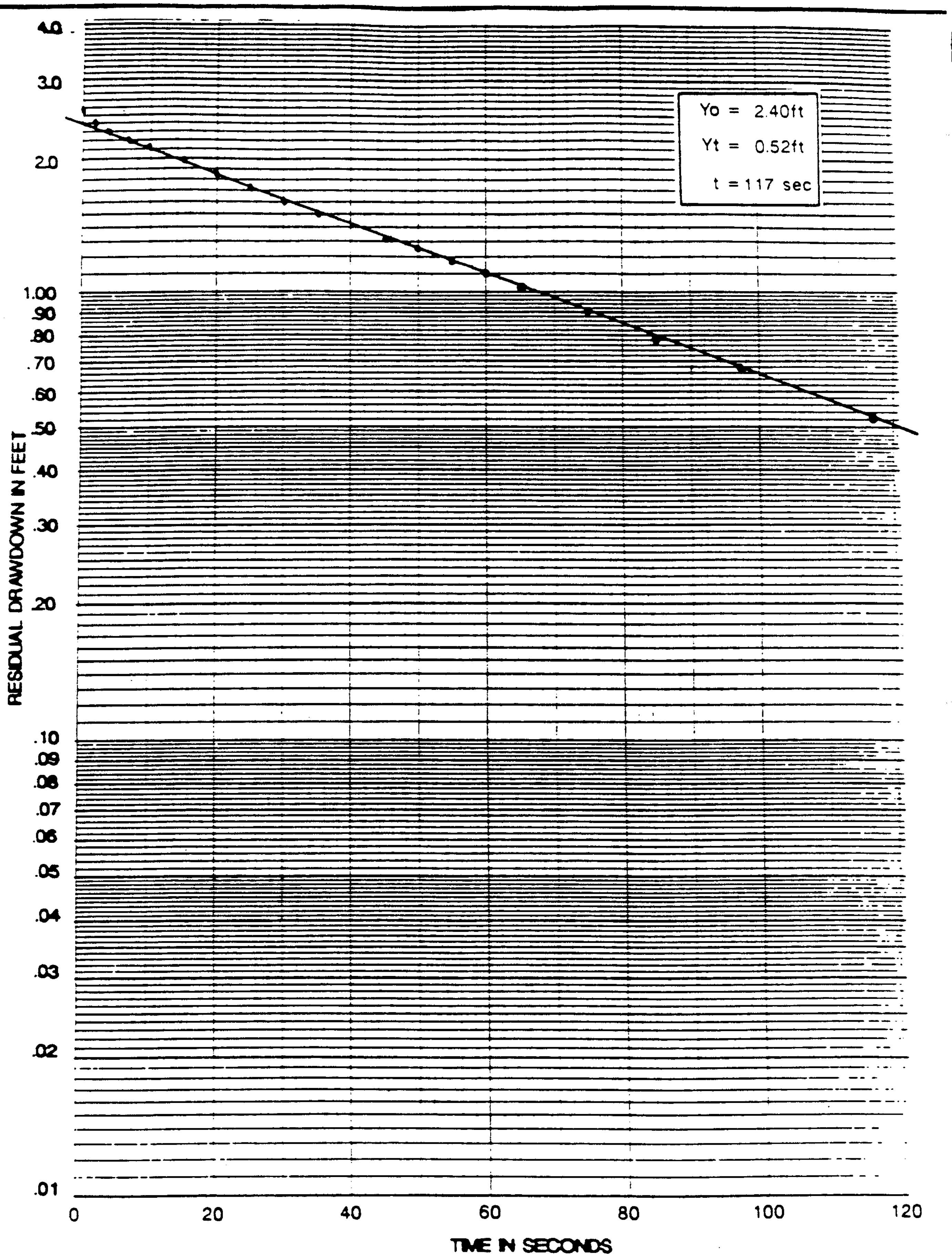


WCC-1D SLUG TEST INSERT

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.18

Woodward-Clyde Consultants

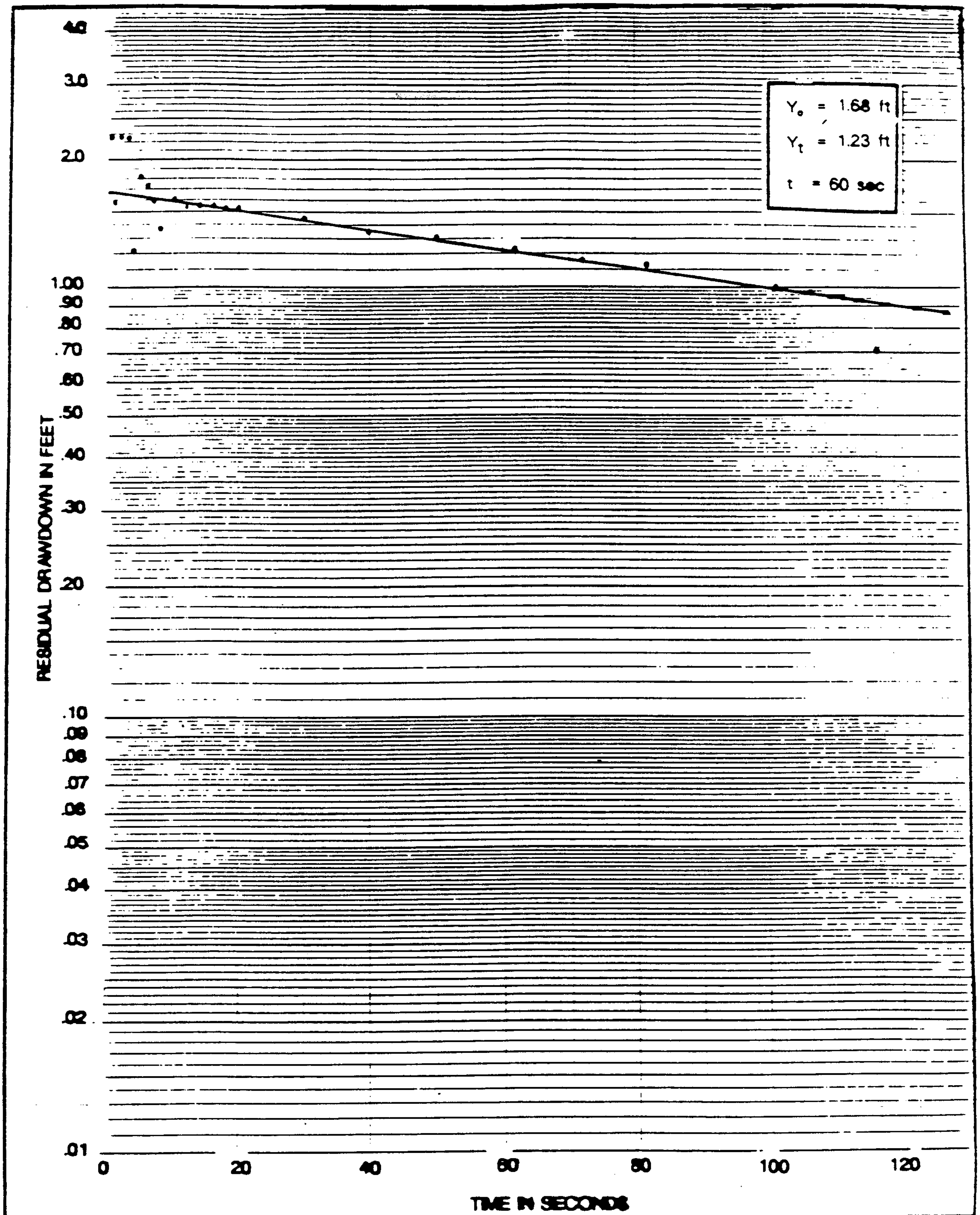
BOE-C6-0210617



WCC-1D SLUG TEST WITHDRAWAL

Project No.: 8941863J	Date: OCT 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.19

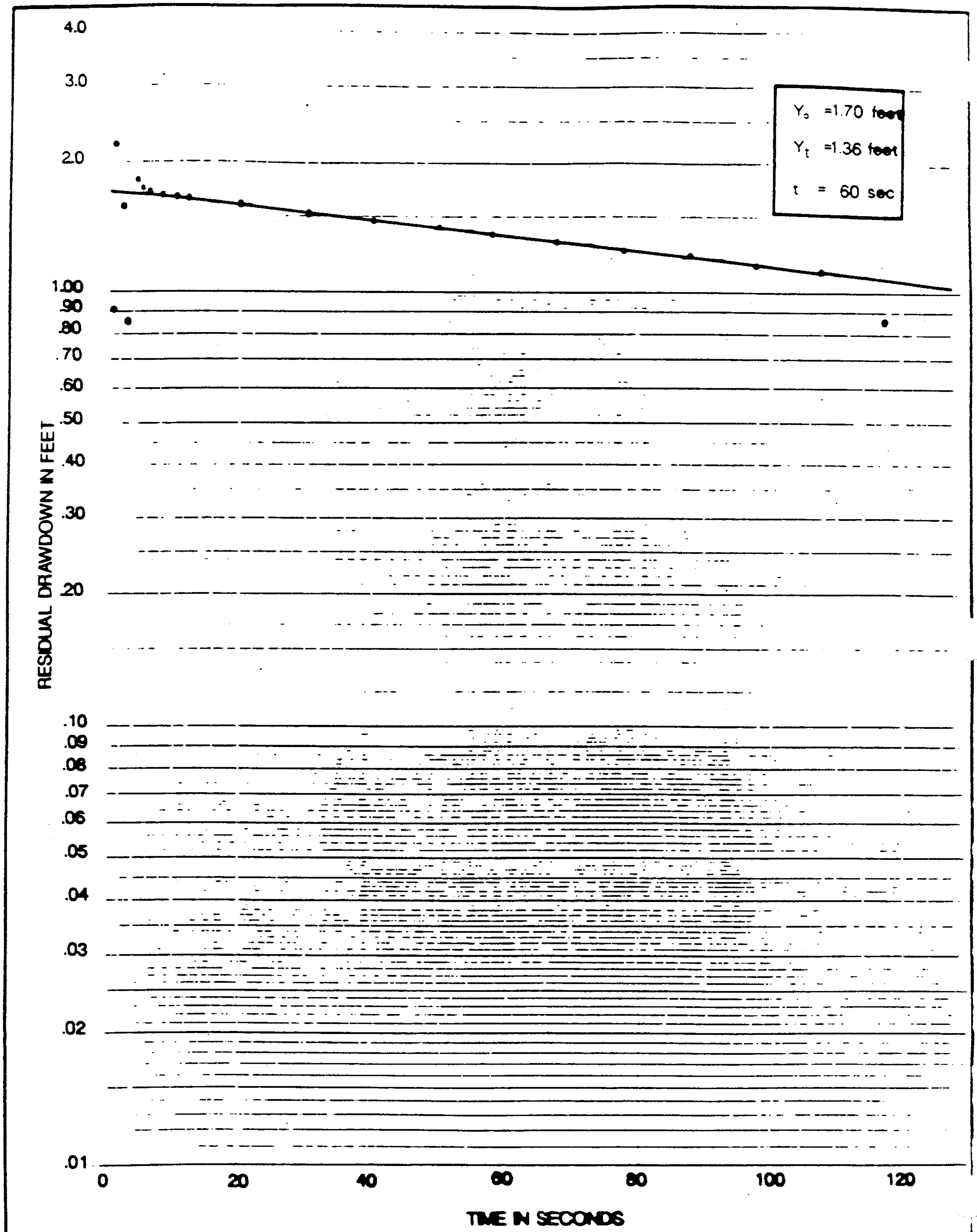
Woodward-Clyde Consultants



WCC-3D SLUG TEST INSERT

Project No.: 8941863J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.20

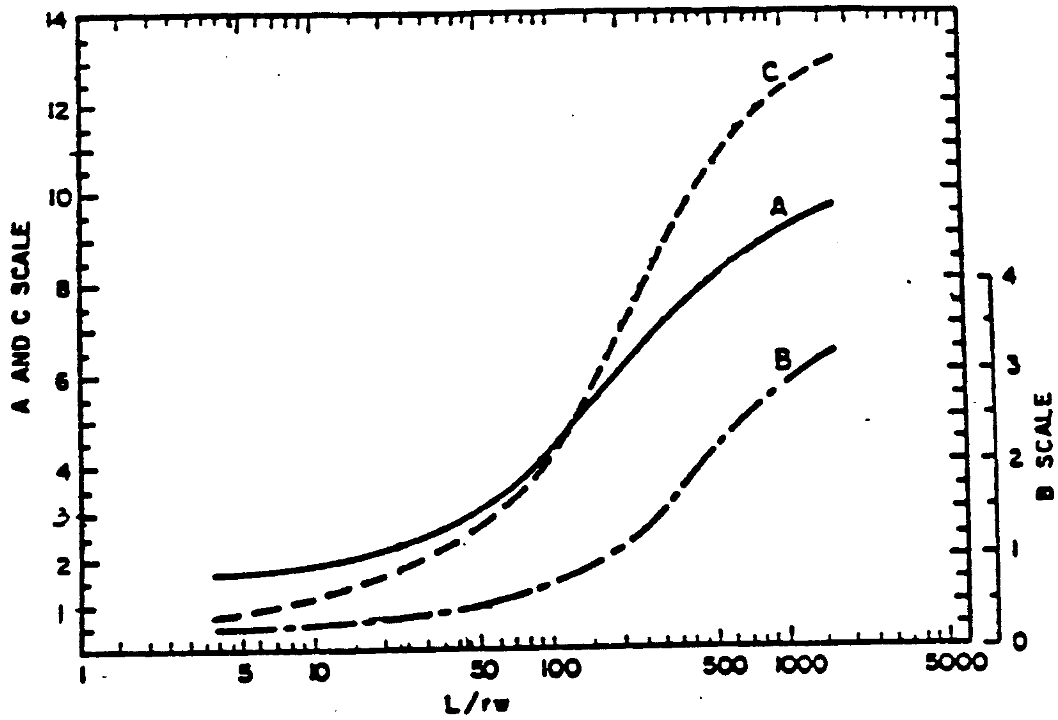
BOE-C6-0210619



WCC-3D SLUG TEST WITHDRAWAL

Project No.: [illegible]	Date: AUGUST [illegible]	Project: DOUGLAS AIRCRAFT CO. - TORRANCE	Fig. A.21

BOE-C6-0210620



Bouwer and Rice A, B and C Coefficient Curves

Project No.: 8941863J	Date: AUGUST 1989	Project: DOUGLAS AIRCRAFT COMPANY	Fig. A.22

Woodward-Clyde Consultants

BOE-C6-0210621

Appendix B

DEL AMO STUDY AREA

Summaries of Aquifer Test Results

TABLE 4.2-1
SUMMARY OF CONSTANT RATE DISCHARGE TESTS
DEL AMO AQUIFER TESTING

Well ID	Test Date(s)	Pumping Rate, Q (gpm)	Time Pump On	Time Pump Off	Total Pumping Time (minutes)
Upper Bellflower Aquitard					
SWL0005	2/29/96	0.7	13:31:20	19:14:00	341
SWL0006	3/6/96	0.35	9:21:00	21:33:00	732
SWL0009	3/5/96	0.29	9:10:00	22:30:00	800
SWL0012	3/13/96	0.86	9:45:00	15:38:00	353
SWL0016	2/20/96	0.8	9:01:00	21:35:00	754
SWL0017	3/19/96	0.4	12:25:00	0:30:00	725
SWL0021	3/22/96	0.2	8:43:00	20:43:00	720
SWL0039	1/19/96	1.8	9:39:00	21:53:00	734
SWL0042	3/20/96	1.0	9:40:00	21:51:00	731
SWL0046	1/18/96	0.9	10:34:00	22:50:30	737
SWL0057	2/21/96	0.75	9:09:00	21:26:00	737
Middle Bellflower B Sand					
SWL0011	3/15/96	10.8	10:00:00	22:20:00	740
SWL0023	4/25/96- 4/26/96	9.9	09:40:00	13:00:00	1,640
SWL0037	3/23/96	4.8	8:35:00	20:36:00	721
SWL0047	3/12/96	4.6	9:47:35	21:50:00	722
SWL0049	2/28/96	5.0	10:22:00	23:00:00	758
XMW-28	3/24/96	4.0	10:40:00	21:25:00	645
Middle Bellflower C Sand					
SWL0014	4/22/96	4.8	12:00:02	17:56:00	356
Gage					
XDA-1B	5/3/96	25.0	10:33:00	21:30:00	657

TABLE 4.2-2
SUMMARY OF AQUIFER TESTING RESULTS
THEIS RECOVERY METHOD
DEL AMO AQUIFER TESTING

Well ID	Transmissivity, T (ft^2/minute)	Aquifer Thickness, b (feet)	Hydraulic Conductivity, K (feet/day)
Upper Bellflower Aquitard			
SWL0005	0.02	17.6	1.6
SWL0006	0.025	21.6	1.7
SWL0009	0.004	24.1	0.2
SWL0012[1]	0.059	16.5	5.2
SWL0016	0.046	13.4	4.9
SWL0017	0.016	16.7	1.4
SWL0021	0.02	16	1.8
SWL0039	0.13	19.3	10
SWL0042	0.02	16.1	1.8
SWL0044[2]	0.001	13.8	0.1
SWL0046	0.023	11.4	2.9
SWL0057	0.053	16.3	4.7
Middle Bellflower B Sand			
SWL0011	0.77	63	18
SWL0023	0.96	65	21
SWL0037	0.50	61	12
SWL0047	0.35	58	9
SWL0049	0.42	12.1	50
XMW-28[3]	0.11	16.1	10

Well ID	Transmissivity, T (ft^2/minute)	Aquifer Thickness, b (feet)	Hydraulic Conductivity, K (feet/day)
Middle Bellflower C Sand			
SWL0014	1.1	58	27
XBF-5[4]	5.5	20	400
XBF-7[4]	1.3	10	190
XBF-9[4]	3.5	19.5	260
XBF-11[4]	2.8	65.1	62
XBF-13[4]	1.3	59.5	32
XBF-15[4]	5	43.5	170
Gage			
XDA-1B	0.98	62	23
XG-5[4]	1.5	61	35
XG-11[4]	1.3	52	31
XG-13[4]	0.92	36.5	36

1 Short pumping time; pumping was terminated at 353 minutes to avoid drawing water level below pump intake.

2 Results for match to head-ratio data from falling-head slug test

3 Well XMW-28 is a water table well that is screened partially in the upper Bellflower and partially in the middle Bellflower B Sand

4 Results from Hargis + Associates' reanalysis of constant discharge aquifer test data collected during Montrose RI/FS using the Theis recovery method (Hargis + Assoc., 1996b)

TABLE 4.2-3

SUMMARY OF AQUITARD VERTICAL HYDRAULIC CONDUCTIVITY
RATIO METHOD TEST RESULTS

Aquifer/ Well	Aquitard/ Well	Time (minutes)	Upper-End Average K_v' (feet/day)	Lower-End Average K_v' (feet/day)
MBFB SWL0023	UBF SWL0024	170	4.9×10^{-1}	2.6×10^{-1}
		500	2.5×10^{-1}	1.4×10^{-1}
		Average	3.7×10^{-1}	2×10^{-1}
MBFC SWL0014	LBF SWL0043	60	9.6×10^{-1}	3.6×10^{-1}
		210	6.1×10^{-1}	2.3×10^{-1}
		Average	7.9×10^{-1}	3×10^{-1}
Gage XDA-1B	LBF SWL0043	72	5×10^{-2}	2×10^{-2}
		312	2×10^{-2}	9×10^{-3}
		Average	3.5×10^{-2}	1×10^{-2}

K_v' = vertical hydraulic conductivity of aquitard

DEL AMO STUDY AREA

Map showing Aquifer Test Well Locations

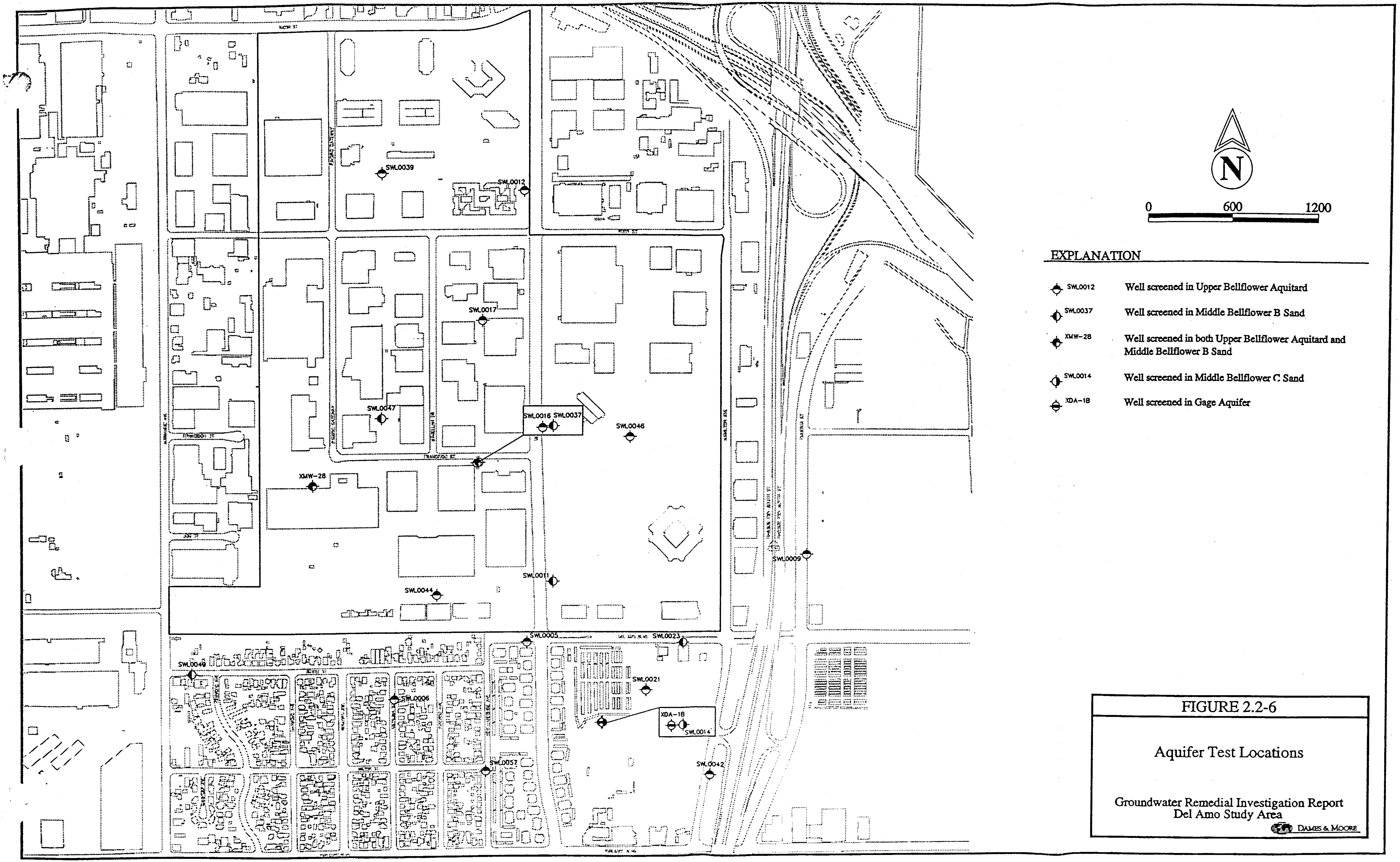


FIGURE 2.2-6

Aquifer Test Locations

Groundwater Remedial Investigation Report
Del Amo Study Area

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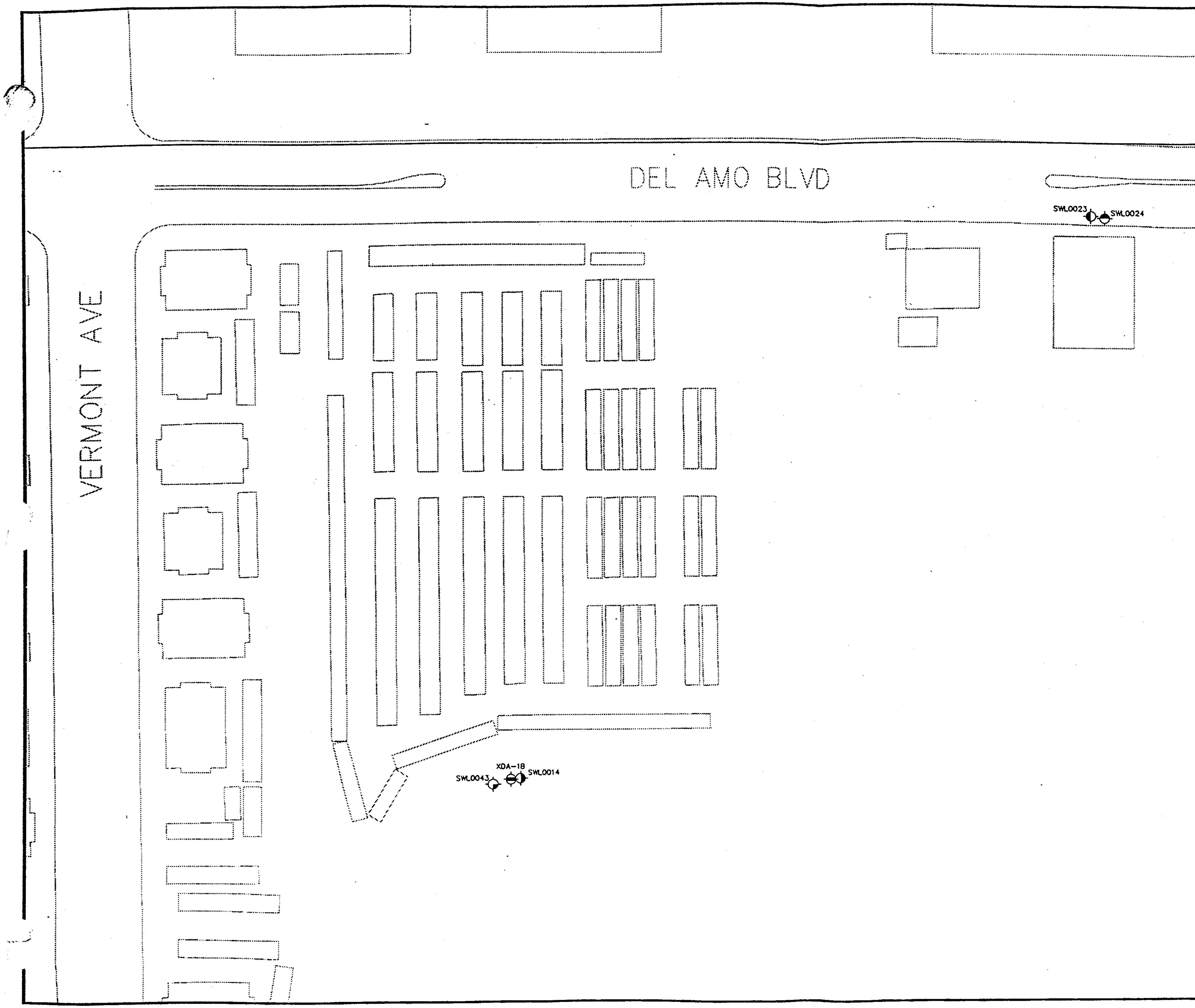

EXPLANATION

SWL0024 Well screened in Upper Bellflower Aquitard

SWL0023 Well screened in Middle Bellflower B Sand

SWL0014 Well screened in Middle Bellflower C Sand

SWL0043 Well screened in Lower Bellflower Aquitard

XDA-1B Well screened in Gage Aquifer

FIGURE 2.2-7

Ratio Test Method Locations

Groundwater Remedial Investigation Report
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